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42D CONGRESS, 2d Session. | HOUSE OF REPRESENTATIVES. | Ex. Doc. No. 121.

REPORT OF THE SUPERINTENDENT

OF THE

UNITED STATES COAST SURVEY,

SHOWING

THE PROGRESS OF THE SURVEY

DURING

THE YEAR 1871.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1874

IN THE SENATE OF THE UNITED STATES,
May 14, 1872.

The following resolution, originating in the Senate February 12, 1872, was concurred in by the House of Representatives May 14, 1872:

Resolved by the Senate, (the House of Representatives concurring,) That there be printed thirty-five hundred extra copies of the Report of the Superintendent of the United States Coast Survey for 1871, of which fifteen hundred shall be for the use of the House of Representatives, one thousand for the use of the Senate, and one thousand for the use of the Superintendent.

Attest:

GEO. C. GORHAM,
Secretary.

LETTER

FROM

THE SECRETARY OF THE TREASURY,

TRANSMITTING

THE ANNUAL REPORT OF THE SUPERINTENDENT OF THE U. S. COAST SURVEY FOR 1871.

FEBRUARY 9, 1872.—Referred to the Committee on Commerce and ordered to be printed.

TREASURY DEPARTMENT, *February* 9, 1872.

SIR: I have the honor to transmit, for the information of the House of Representatives, a report made to this Department by Prof. Benjamin Peirce, Superintendent of the Coast Survey, stating the operations and progress in the survey of the Atlantic, Gulf, and Pacific coasts of the United States during the year ending November 1, 1871.

I have the honor to be, very respectfully,

GEO. S. BOUTWELL,
Secretary of the Treasury.

Hon. JAMES G. BLAINE,
Speaker of the House of Representatives.

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REPORT.

COAST SURVEY OFFICE,
Washington, D. C., December 12, 1871.

SIR: I have the honor to present this detailed report, showing the operations of the parties allotted for the survey of the coast during the year ending with the month of October, and including in a few cases mention of work carried on until this date.

It is a distinguishing feature of the service under my charge, that while it has a specific and direct object in its bearing on the interests of commerce and navigation, the performance involves operations and investigations which almost rival in value the primary function of the survey. The methods and processes used have been at all times the best afforded by science and art, and the form of publication has gained in accuracy and beauty, so that our charts from the first have been unsurpassed by any which have been elsewhere produced. The methods of astronomical observation employed in the survey are now universally adopted, and have greatly increased the precision with which elements of the relative position of places upon the earth are determined. Our deep-sea explorations have incidentally opened new worlds of discovery to the naturalist and the physicist The laws of the tides and of the distribution of magnetism have been traced with increased distinctness, and have been made more intelligible by the observations made in the progress of the survey. And, in the general mention of incidental advantages, it may be added that the necessary connection between the geodetic operations upon the two sides of the continent gives opportunity, the suggestion of which cannot be justly omitted, to take steps for the geodetic survey of the country as the essential foundation of all local surveys, topographical or geological. It opens, moreover, the opportunity of extending to the States of the interior benefits similar to those which have already been afforded to States on the sea-board. The interest manifested in a few determinations of geographical position within the year in the Western States shows a full appreciation of the advantage that must inure from extended operations similar in kind, in the local development of that great region. The few points at the west now in geodetic relation with such as have been determined in the progress of the survey of the coast will be mentioned in the following general summary, whichi s given in accordance with the usage in previous reports. It will be seen that, with the exception of Delaware and Alabama, the survey has been in progress in all the sea-board and Gulf States, and that determinations have been made of latitude and longitude at several points in the interior. In correspondence with the order given in this brief statement, the body of the report will contain short abstracts of the operations in each site of work.

On the coast of Maine the topographical surveys include Somes Sound and Southwest Harbor; several of the Fox Islands which bound Seal Harbor, and others at the entrance of Penobscot Bay; the western shore of that bay between Camden and Belfast and Isleboro', near the entrance to Belfast Bay; the shores of Androscoggin and Cathance Rivers between Brunswick and Bowdoinham; the shores of the Saco; and the coast northward to Spurwink River. The hydrography has developed Prospect Harbor, and the ledges in the vicinity of Moose-a-bec Reach; Somes Sound including Southwest Harbor; Seal Bay and the western channel of Penobscot Bay between Camden and Belfast; Gilkey's Harbor at Isleboro'; ledges near the Fox Islands; the lower parts of the Androscoggin and Cathance Rivers; the vicinity of Cape Porpoise and Stage Island; Winter Harbor; the approaches to Saco River; and the present condition of harbors generally between Cape Small Point and Boston, with reference to accuracy in the sailing directions. Tidal observations have been continued at North Haven in Penobscot Bay, and at the Boston navy-yard. Points have been determined by triangulation on the Androscoggin and Cathance Rivers; and others in geodetic connection with primary stations in New Hampshire. At Cambridge, Mass., astronomical observations were made to deter-

mine longitude at several points in the Western States. Special examinations at Edgartown, Vineyard Haven, and Nantucket Harbor, were conducted with a view to determine the causes which affect the harbor facilities. Plane-table work done in Rhode Island completes the detailed survey of Narragansett Bay, including the coast in the vicinity of Point Judith. Points have been determined for extending the topography westward. Station-marks along the coast of Connecticut and Long Island have been examined with reference to their preservation. The triangulation and topography in this section include work near New Haven; the shore-line survey of the greater part of Lake Champlain, and the development of its channels between Burlington, Vt., and Plattsburgh, N. Y. Special hydrographic operations have been conducted in Hudson River, and in New York Harbor, including tidal observations; and the survey of Newark Bay has been extended to include the navigable rivers which enter it. In New Jersey the field-work comprised operations in the vicinity of Mount Holly, Great Bay, and Little Egg Harbor. In Delaware River a close hydrographic survey develops the vicinity of League Island, and the lower part of the Schuylkill. The sites of work in Maryland and Virginia are the Broadwater on the Atlantic coast, Calvert Station, Tangier Island, and Wolf Trap, in Chesapeake Bay; the Severn, Chester, and Choptank Rivers; James River, and tidal observations, as heretofore, at Old Point Comfort. The main triangulation has been continued along the Blue Ridge, and magnetic observations have been recorded at Washington, D. C. On the coast of North Carolina the survey has been advanced by additional work in the waters of Pamplico Sound; latitude, azimuth and magnetic observations near Portsmouth, N. C.; the development of Pamplico River to the vicinity of Washington; soundings on the Hatteras Shoal, and the plane-table survey of Bogue Sound and the adjacent coast. Progress has been made on the coast of South Carolina by the development of parts of the Combahee, Chechesse, and Wright's River, with others in the system of inside sea-water channels. On the coast of Georgia and Florida, the work of the year includes Amelia and Talbot Island, the shores and approaches from seaward of Nassau Sound, the sea-water channels between the Saint Mary's and Saint John's Rivers, and Matanzas River below Saint Augustine. Further development has been made by hydrographic operations in the vicinity of the Tortugas. On the Gulf coast the principal channel at Cedar Keys was sounded, as also the unfinished part of Saint George's Sound; other operations were conducted at Saint Joseph's Bay and Saint Andrew's Bay. Farther westward the Gulf coast, including Santa Rosa Sound, was developed from Choctawhatchee entrance to the entrance of Pensacola Bay. In the interior of this section, latitude, longitude, and the magnetic elements were determined at Cleveland and Columbus in Ohio, and at Falmouth, Oakland, and Shelbyville in Kentucky. On the Gulf coast the eastern part of Lake Pontchartrain was sounded. Operations on the coast of Louisiana include part of the Chandeleur Islands, the Mississippi River to Point La Hache, the Gulf approaches to the delta of that river, and hydrographic work in the vicinity of Trinity Shoal. In the interior of this section points have been determined by triangulation across the Mississippi River in the vicinity of Saint Louis. On the coast of Texas the hydrographic work has been completed in Matagorda Bay and its branches, and soundings have been extended southward in its connecting waters. In the interior of this section observations were made for latitude and longitude at Chetopa, in Kansas.

On the coast of Lower California some positions have been determined in advance of the hydrographic reconnaissance, which is intended for developing the dangers in navigation between Panama and San Diego. A special survey has been made within the year at Magdalena Bay. Operations north of San Diego include in triangulation, topography, or hydrography the coast of California, at Bahia Ona, and a stretch in the vicinity of Point Conception; Santa Barbara Island; San Miguel Island; the vicinity of San Luis Obispo, and San Simeon; soundings in the approaches of San Francisco Bay, and others by the same party in the neighborhood of a reported shoal in the Pacific; hydrographic developments inside of San Francisco Bay; the survey of the north side of the entrance; additional work at Oakland; and tidal observations at San Diego and San Francisco. North of that port the field-work has been continued near Mendocino Bay and near Shelter Cove; in the vicinity of the False Klamath, and at Crescent City; and astronomical and magnetic observations have been made at San Diego, San Francisco, Eureka, and Crescent City. At the request of the Department, special tests were made of the coin weights in use at the branch mint in San Francisco.

On the coast of Oregon and Washington Territory progress has been made in the survey near Cape San Sebastian, and the Orford Reef has been developed. Field operations include also parts of the Columbia River, Shoalwater Bay, tidal observations at Astoria, and work in the vicinity of Seattle. The triangulation, topography, and hydrography have been advanced also in the Strait of Fuca, and in Admiralty Inlet, and several local surveys have been made in those waters.

On the western coast the season was generally unfavorable for field operations on account of high winds, heavy fogs, and the smoke from burning forests in Oregon and in Washington Territory. Nevertheless, the work done is beyond the average of past seasons. Longitude has been determined within the year at San Diego and at Seattle, so that the most remote detached triangulations on the Pacific Coast are now in known geographical relation. Astoria and Eureka will be ascertained in longitude when telegraphic facilities permit.

There is now a large extent of well-defined shore-line ready for the operations of the hydrographic party, which is at present on the passage to San Francisco, and provided with an ample outfit for off-shore soundings.

When the appropriation for the present fiscal year became available, a party, previously organized, was sent from San Francisco, without delay, to make such development in hydrography, and such other observations of interest and value as may be practicable in the vicinity of the Aleutian Islands, off the coast of Alaska. The party sailed in August, but there is yet no advice of the arrival of the vessel at her destination.

Within the year laborious computations have been completed, giving final values for the longitude of points intermediate between the Atlantic and the Pacific Coasts. Of these, the principal ones are Omaha, Salt Lake City, and San Francisco.

Computations are in progress for determining the transatlantic longitude, which depends upon the observations made last year at Brest and Duxbury.

The discussion is continued, of full series of tidal observations, with reference to the construction of tables of prediction.

In the Coast-Survey Office the operations of the several divisions have kept pace with the field-work. Twenty new charts have been published, including three new editions of charts made needful by extensive changes. Fifty-eight charts have been in hand in the drawing division, of which nine were commenced within the year. Of the various engraved charts, about ten thousand copies have been printed, and an equal number of copies distributed from the Office. Of the manuscript maps on file in the archives, sixty-six have been copied or traced within the year, to meet calls for information from various branches of the public service.

Tide-tables for the ports of the United States, for the year 1872, have been computed and issued from the Office.

In the hydrographic division, special care has been taken in regard to the marked places of buoys on the published charts. Most of the sea-marks liable to shift have been carefully determined in position, and marked on the charts which admitted of such changes without detriment to the sailing directions.

Specifications for the construction of several steam-vessels and schooners, to replace such as had been worn out in the service, were carefully drawn up by the hydrographic inspector, when means became available under the appropriation for that object. The smaller vessels were completed first, and went into service in the winter of 1870. Within the present year two steam-vessels were fitted out, and are now employed in the duty for which they were intended.

The internal arrangements of all the new vessels are admirably adapted to the demands of the service. Their qualities as sea-boats and fast sailers have testified to the excellence of their models and to the ability of Captain Patterson as a naval constructor.

The iron steamer Hassler, intended for hydrographic service on the Pacific coast of the United States, was launched at Kaighn's Point, N. J., on the 12th of September of the present year. While the hull of the vessel was under construction, the officer detailed by the honorable Secretary of the Navy for the command of the hydrographic party gave personal attention to the details specified in the plan of the hydrographic inspector. As soon as possible the steamer was rigged for sea, and at the end of October trial was made of the engine in a run from Philadelphia to Boston. Commander Johnson was entirely satisfied with the performance of the vessel as a sea-

boat, and with special gratification reported that a rate of about seven and a half knots was maintained during the day by the consumption of only two and a half tons of coal. This unequaled economy in fuel deserves attention, which will doubtless be more closely attracted by the working of other engines similar to that now in the steamer Hassler.

The rigging, outfit, and final adjustment of the machinery of the steamer for a long voyage were completed at the Charlestown navy-yard, where also the magnetic condition of the ship was finally tested, with reference to the use of compasses in steering at sea. This important service was performed by Assistant Charles A. Schott, aided by Dr. Thomas Hill, of Waltham, Mass. The officers of the vessel are fully informed in regard to the means requisite for maintaining the effective use of the compasses.

The steamer Hassler is a three-masted screw-propeller of three hundred and fifty tons, and is believed to be in all respects admirably designed for general hydrographic service. Incidental duty, in which the vessel is now employed, will be briefly mentioned under the next head.

The second steamer, built and fitted out under the supervision of the hydrographic inspector, and designed for hydrographic work on the coast of the Atlantic and Gulf of Mexico, is of two hundred and eighty tons burthen. This vessel was launched in August and was named after the late Superintendent A. D. Bache. The hydrographic party now on board, under Lieutenant Commander John A. Howell, U. S. N., is engaged in running lines of soundings and noting temperatures with a view of developing the characteristics of the Gulf Stream. In general the vessel will be employed for off-shore hydrography, in gathering material for the larger sailing charts.

VOYAGE OF THE COAST-SURVEY STEAMER HASSLER.

As already mentioned, the Hassler was planned and built for hydrographic service on the western coast of the United States. In her transfer from the Atlantic side the intelligent and energetic officers detailed by the honorable Secretary of the Navy for duty in that vessel would undoubtedly have made valuable observations; they would have continued the researches which were commenced by officers of the Coast Survey upon the phenomena of the ocean, and which have become the stimulus to general scientific inquiry. The deep-sea soundings have suggested the existence of intimate relations between the currents and natural channels of the ocean; the dredgings have brought to light new fauna peculiarly related to the natural history of the globe; and even the temperatures and densities of the ocean at various depths, and in different localities, appear to be subject to laws worthy of the most careful investigation. Other nations have recognized the significance of the facts first developed by the Coast Survey, and have pursued corresponding inquiries under conditions much less opportune than those presented by the incidental voyage of the steamer Hassler around Cape Horn. But it is evident that whatever general interest may be felt by the Navy officers on board, and however anxious they may be to collect data, their labors must be greatly facilitated by the assistance of those who have advanced, through years of patient study and comparison, toward the end sought in such investigations. Without the co-operation of men eminent in science, the voyage would be much restricted in time, and correspondingly restricted in special results. I therefore felt it to be a duty not to limit this voyage to the least requirements of navigation, but to take advantage of the occasion for the solution of momentous questions, or at least to add something to the knowledge now generally admitted to be of special consequence by its direct bearing upon important unsolved inquiries. The wish toward that end has been nobly met by the men of science and their friends. At my invitation the direction of the desired scientific researches has been undertaken by Professor Louis Agassiz, and he has been assisted with large means furnished by enlightened men of fortune. He has undertaken the expedition in the spirit which has pervaded his life—with intense devotion to the interests of his adopted country, and with increasing desire that its scientific fame may be commensurate with the rank which we otherwise hold amongst the nations of the civilized world. The departure from sight and daily intimacy of that eminent man, upon a long and, it may be, perilous voyage, leaves a void which cannot be filled. But while the exploration intended is a consummation worthy of his great life, he alone is equal to the grandeur of the enterprise. We hope to meet him on the shores of the Pacific Ocean in the vigor of his pristine strength.

Professor Agassiz is accompanied by Thomas Hill, LL. D., ex-president of Harvard University; L. F. Pourtales, esq., Assistant in the Coast Survey; and Dr. Franz Steindachner, all of them experienced observers.

Commander Philip C. Johnson, U. S. N., now in command of the steamer Hassler, is assisted in the hydrographic service by Lieut. Commander Charles W. Kennedy, Lieut. Murray S. Day, and Masters Henry B. Mansfield and Edward W. Remey. With an outfit sufficient for all the observations that will be practicable within the period allotted for researches, the vessel started on her voyage from Boston on the 4th of the present month.

ESTIMATES.

In some general remarks which accompanied my estimates in September last for the work of the next fiscal year, and of which a copy will be included with this report, attention was called to the interest now alive in the interior States in regard to accuracy in geographical positions. A few additional remarks are suggested by incidents which have since transpired.

By means of a limited number of well-ascertained points in each State, the existing maps might be corrected by State authorities, and used in the improved form, as they are used now, for general purposes. Special needs will in time press for the minute survey, first of one part and then another, until the whole area of each State is correctly mapped. If, therefore, positions are determined in advance, and sufficient in number for the area, more or less, after serving for the partial correction of State maps, the same points avail for the State authorities in making future topographical and geological surveys. Secured for identification by marks set in the ground below the reach of needful operations in tillage, and protected from willful displacement by State law, the points at places not to be speedily developed may await for years the occasion for reference to them. Instances of the recovery of old stations will be mentioned in this report under the head of *station-marks*, in Section II. But, to be in true relation, points must be determined in reference to their connection with each other, and economy in fixing them is in proportion to their number. One only, settled in latitude and longitude, involves far greater cost than the average of ten or more brought into connection with it by angular measurement. It need not be here explained that the longitude of any one in a series of points determines all adjacent positions that have been properly joined by triangulation. Within the year, a few geographical positions have been in this way determined in the vicinity of Saint Louis, and others in the States of Ohio, Illinois, and Kentucky, under a proviso in the last appropriation bill which allotted a small sum for such purposes. The results very forcibly illustrate the wisdom and expediency of giving without delay, as can be done at small cost, a sure basis for surveys that may be undertaken at the West by State authorities. Last year the longitude of Saint Louis was well ascertained, a station there being of importance as one of several at which observations were made on the solar eclipse of 1869.

At the state-house in Columbus, Ohio, the longitude deduced from observations made in October last by one of our most experienced assistants, proves that the previously accepted position is in error by as much as three miles. This discrepancy was not known when the governor of Ohio applied for the benefit of the provision made by Congress.

The points proposed for determination in the vicinity of the Mississippi are from ten to eighteen miles apart. It is intended to connect all of them with the nearest section corner of the surveys made for the General Land-Office. Hence the work done by the Government in the geodetic connection of the Atlantic with the Pacific Coast, as proposed in the estimates, incidentally avails for the geographical adjustment of large and populous areas at the West, and presents a motive for early action in regard to correct State maps, in the issue of which the Government has collateral interest, through the requirements of the postal service.

Early in the present season, aid given for the direct uses of the Department of the Interior, has added a point still further westward to our list of well-ascertained positions. At the request of the Commissioner of the General Land-Office, latitude and longitude were determined at a station on the southern boundary of Kansas, near the ninety-fifth meridian, as will be noticed under the head of Section IX in the body of this report.

Telegraphic facilities now extending into the interior afford ready means for correcting longitude by the process first used and now mainly depended upon in the survey of the coast. Many points

along the sea-board, and several in the middle of the continent have been already fixed by the application of that method.

A copy of the detailed estimates for continuing the work of the survey during the fiscal year 1872–'73, which were submitted in September last, is here subjoined:

For general expenses of all the sections, namely: Rent, fuel, materials for drawing, engraving and printing, and for transportation of instruments, maps, and charts; for miscellaneous office expenses, and for the purchase of new instruments, book, maps, and charts, will require	$25, 000
SECTION I. *Coast of Maine, New Hampshire, Massachusetts, and Rhode Island.* FIELD WORK.—To continue the triangulation of the branches of Passamaquoddy Bay, and to extend the work so as to include the northeastern boundary along the *Saint Croix River;* to determine subsidiary points on the coast of Maine for the use of plane-table parties; to continue the topography of the western shore of *Passamaquoddy Bay*, the estuaries of *Frenchman's Bay*, that of *Mount Desert Island*, and of the islands and shores of the *Penobscot* and of *Isle au Haut Bay*, and that north of *Saco Bay;* to continue off-shore soundings along the coast of Maine, and the hydrography of *Frenchman's Bay, Goldsborough Bay, Penobscot Bay*, and *Isle au Haut Bay;* to continue tidal and magnetic observations, and to make such astronomical observations as may be requisite in the section. OFFICE-WORK.—To make the computations from field observations; to continue the drawing and engraving of General Coast Chart No. 1, (*Quoddy Head to Cape Cod;*) to continue the drawing and engraving of Coast Chart No. 4, (*Naskeag Point to White Head Light, including Penobscot Bay;*) to complete No. 6, (*Kennebec entrance to Wood Island Light;*) No. 7, (*Seguin Light to Cape Porpoise Light;*) and Coast Chart No. 13, (*from Cuttyhunk to Point Judith, including Narragansett Bay;*) to draw and engrave preliminary charts of *South West Harbor* and *Somes Sound*, (*Mount Desert Island;*) to continue the drawing and engraving of the harbor and river charts of the coast of *Maine*, and complete charts of *Narragansett Bay* and *Lake Champlain*, will require	80,000
SECTION II. *Coast of Connecticut, New York, New Jersey, Pennsylvania, and part of Delaware.* FIELD-WORK.—To make supplementary astronomical observations; to continue the triangulation of *Connecticut River*, and plane-table work near New Haven; to complete the triangulation between *Mount Holly* and *Barnegat Light-house, New Jersey;* to continue the detailed topography of the coast of *New Jersey* below Little Egg Harbor and that of the shores of the *Hudson River*, above Haverstraw; to execute such supplementary hydrography as may be required in the vicinity of *New York Bay* and *Delaware Bay;* to continue the tidal observations. OFFICE-WORK.—To make the computations and reductions of field-work; to continue the drawing and engraving of Coast Charts Nos. 21, 22, and 23, (*from Sandy Hook to Cape May*,) will require	15,000
SECTION III. *Coast of part of Delaware, and that of Maryland and part of Virginia.* FIELD-WORK.—To make the requisite astronomical and magnetic observations in this section; to connect the outer coast triangulation with that of *Chesapeake Bay*, across the Peninsula; to continue the primary triangulation parallel to the coast southward along the *Blue Ridge* in Virginia and North Carolina; to connect with the primary, the triangulation of the *Upper Potomac;* to continue the topography of the sea-coast and bays of Virginia, north of the *Broad Water;* and that of the shores of the *James River*, including the requisite triangulation; to complete the shore-line survey and hydrography of bays and inlets remaining unsurveyed in this section; to continue tidal observations. OFFICE-WORK.—To make the computations from field-work; to complete the drawing and engraving of Coast Charts Nos. 29 and 30, (*from Chincoteague Inlet to Cape Henry*,) and of General Coast Chart No. 4, (*approaches to Delaware and Chesapeake Bay;*) to continue work on a chart of the lower part of *James River*, and to draw and engrave the supplementary surveys of the estuar s of *Chesapeake Bay*, will require	38,000

SECTION IV. *Coast of part of Virginia and part of North Carolina.* FIELD-WORK.—To continue the triangulation of *Pamplico Sound*, and to make the requisite astronomical and magnetic observations; to continue the topography of the western shores of *Pamplico Sound*, and complete that between *Neuse River* entrance and *Core Sound;* to continue the off-shore hydrography of the section and that of *Currituck* and *Pamplico Sounds*, and their estuaries; and to continue observations on the tides and currents. OFFICE-WORK.—To make computations and reductions; to draw and engrave Coast Charts No. 38 and No. 39, (*Nag's Head to Cape Hatteras;*) to continue the drawing and engraving of Charts Nos. 42, 43, and 44, (*Pamplico Sound and estuaries;*) to complete No. 50, (*Cape Fear River and approaches to Wilmington;*) and to continue work on the chart of *Pamplico River*, will require....... $38,000

SECTION V. *Coast of South Carolina and Georgia.* FIELD-WORK.—To make the requisite astronomical and magnetic observations, and the triangulation between *Little River* and *Winyah Bay*, South Carolina; to continue the topography between *Winyah Bay* and *Cape Romain;* to complete the topography and sound the inland water-passages between *Charleston Harbor* and *Savannah River;* to continue the off-shore hydrography of the section and tidal observations. OFFICE-WORK.—To make the computations; to continue the drawing and engraving of General Coast Chart No. VII, (*from Cape Romain to Saint Mary's River;*) complete Coast Charts No. 56 and 57, (*from Savannah River to Saint Mary's River;*) and charts of *Doboy* and *Altamaha Sounds*, *Saint Andrew's Sound*, and the inland tide-water communication along the coast of *Georgia*, will require.. 40,000

SECTION VI. *Coast, Keys, and Reefs of Florida.* FIELD-WORK.—To determine the longitude of points on the western coast of Florida; to continue the triangulation and topography from *Matanzas Inlet* southward towards *Mosquito Inlet;* to continue the survey of *Tampa Bay;* to complete the hydrography of the *Florida Reef*, and that of the bay of Florida; to make explorations in the *Gulf Stream*, and the tidal and magnetic observations. OFFICE-WORK.—To make the computations from field observations; to draw and engrave additions to off-shore Chart No. X, (*Florida Straits*,) and No. XI, (*Key West to Tampa Bay;*) and engrave Coast Charts No. 70 and No. 71, (*Key West to Tortugas*,) will require................................ 40,000

SECTION VII. *Gulf Coast of the Florida Peninsula north of Tampa Bay and coast of West Florida.* FIELD WORK.—To continue the triangulation and topography of *Chattahoochee Bay*, and of the *Gulf Coast* eastward and westward from it; to measure a base of verification, and to make such astronomical and magnetic observations as may be requisite in the section; to survey and sound the entrance to the *Suwanee River;* to complete the hydrography of *Saint George's Sound;* and to continue the tidal observations. OFFICE-WORK.—To make the computations from field-work; to continue the drawing and engraving of Coast Charts No. 82 and No. 83, (*from Ocilla River to Cape San Blas;*) of General Coast Chart No. XIII, (*Cape San Blas to Mobile entrance*,) and of Coast Charts No. 86 and No. 87, (*Choctawhatchee entrance to Mobile Bay*,) will require 30,000

SECTION VIII. *Coast of Alabama, Mississippi, and part of Louisiana.* FIELD-WORK.—To extend the triangulation westward from the *Mississippi Delta*, along the *Gulf Coast*, and to make the astronomical and magnetic observations required in this section; to continue the survey of the *Mississippi River*, and determine points in the vicinity of *Saint Louis* and *Cincinnati;* to continue the hydrography of the *Mississippi* between the head of the Passes and *New Orleans;* to complete the survey to the northward of *Isle au Breton Sound*, and to make the tidal observations. OFFICE-WORK.—To make the computations pertaining to field-work; to continue the drawing and engraving of the General Chart No. XIV, (*Gulf Coast between Mobile Point and Vermilion Bay;*) to complete Coast Chart No. 91, (*Lake Borgne and Lake Pontchartrain;*) continue No. 92 and No. 93, (*Chandeleur Islands to Southwest Pass;*) and complete No. 94, (*Mississippi Delta and River*,) will require 50,000

SECTION IX. *Coast of part of Louisiana and Coast of Texas.* FIELD-WORK.—To measure a base-line for verification; to continue the triangulation and topography of *Madre Lagoon,* from *Corpus Christi Bay* southward; to complete the hydrography of *San Antonio* and *Espiritu Santo Bays;* to continue the off-shore hydrography, and to make the requisite tidal observations. OFFICE-WORK.—To make the office computations; to continue the drawing and engraving of General Chart No. XVI, (*Gulf Coast from Galveston to the Rio Grande,*) and to engrave charts of *Corpus Christi Pass, Aransas Pass,* and *Pass Cavallo,* will require $35,000

Total for the Atlantic Coast and Gulf of Mexico $391,000

The estimate for the Western Coast of the United States is intended to provide for the following progress in the survey:

SECTION X. *Coast of California.* FIELD-WORK.—To make the requisite observations for latitude, longitude, and azimuth, at stations on the coast; to extend the triangulation and topography from *Gaviota* to *Point Conception* and *Point Arguello,* and the survey north and south of *Shelter Cove;* for the topography of *Tamal Pais,* and of the southeast *Farallon;* to extend the topography between *San Gabriel River* and *San Juan Capistrano;* to continue that of the coast south of *San Simeon,* and from *San Luis Obispo* to *Point Sal;* also from *Cuffee's Cove* towards *Mendocino Bay;* to continue the plane-table survey of the *Santa Barbara Islands,* and make the requisite triangulation; to continue the hydrographic reconnaissance between *San Diego* and *Panama,* and soundings in the western part of the *Santa Barbara Channel;* to extend the coast hydrography from *False Klamath* northward to the upper limit of the section; to continue tidal observations. OFFICE-WORK.—To compute results from the field records; to draw and engrave preliminary charts of the coast from *Point Vincente* to *Point Conception,* including *Santa Barbara Channel,* and of the coast from *Humboldt Bay* to *Trinidad Head;* to make additions to the General Chart, showing the coast between *San Diego* and *Cape Mendocino,* and for the issue of a chart of the vicinity of *Point Saint George,* including *Crescent City Harbor;* also for operations in—

SECTION XI. *Coast of Oregon and of Washington Territory.* FIELD WORK.—For the determination of latitude, longitude, and azimuth, at stations in the section; to continue the triangulation and topography from *Cape San Sebastian* towards *Port Orford,* and include the hydrography of the *Orford Reef;* to extend the detailed survey of *Shoalwater Bay* southward; to continue the topography of the shores of *Columbia River;* to extend the hydrography of the coast of *Oregon* southward from *Cape San Sebastian;* to continue the topography and requisite triangulation of islands in *Washington Sound;* to extend the hydrography in their vicinity, and the survey in *Puget's Sound;* to make tidal observations. OFFICE-WORK.—To make computations; to draw and engrave charts of *Orford Reef, Port Discovery,* and *Washington Harbor;* and to make additions to the charts of *Washington Sound, Puget's Sound,* and of the coast from *Cape Mendocino* to *Vancouver Island;* and for operations in—

SECTION XII. *Coast of Alaska.*—To continue the hydrographic reconnaissance in the vicinity of the *Aleutian Islands,* with observations on the tides and currents; to draw and engrave the results of the explorations; and to make additions to the three hydrographic sheets of the coast of *Alaska,* will require $240,000

For extending the triangulation of the coast survey so as to form a geodetic connection between the Atlantic and Pacific Coasts of the United States, including compensation of civilians engaged in the work, per act of March 3, 1871: *Provided,* That the triangulation shall determine points in each State of the Union which shall make requisite provision for its own topographical and geological surveys 30,000

For pay and rations of engineers for the steamers used in the coast survey, no longer supplied by the Navy Department, per act of June 12, 1858	$10,000
For continuing the publication of the observations made in the progress of the coast survey, including compensation of civilians engaged in the work, per act of March 3, 1843, the publication to be made at the Government Printing Office	10,000
For repairs and maintenance of the complement of vessels used in the coast survey, per act of March 2, 1853	45,000

The annexed table shows in parallel columns the appropriations made for the fiscal year 1871–'72, and the estimates now submitted for the fiscal year 1872–'73:

Objects.	Estimated for fiscal year 1872–'73.	Appropriated for fiscal year 1871–'72.
For continuing the survey of the Atlantic and Gulf coasts of the United States, and Lake Champlain, including compensation of civilians engaged in the work, and excluding pay and emoluments of officers of the Army and Navy, and petty officers and men of the Navy employed in the work, per act of March 3, 1843	$391,000	$391,000
For continuing the survey of the western coast of the United States, including compensation of civilians engaged in the work, per act of September 30, 1850	240,000	240,000
For extending the triangulation of the Coast Survey so as to form a geodetic connection between the Atlantic and Pacific coasts of the United States, and assisting in the State surveys, including compensation of civilians engaged in the work, per act of March 3, 1871	30,000	15,000
For pay and rations of engineers for the steamers used in the Coast Survey, no longer supplied by the Navy Department, per act of June 12, 1858	10,000	5,000
For continuing the publication of the observations made in the progress of the Coast Survey, including compensation of civilians engaged in the work, per act of March 3, 1843, the publication to be made at the Government Printing Office	10,000	10,000
For repairs and maintenance of the complement of vessels used in the Coast Survey, per act of March 2, 1853.	45,000	45,000
Total	726,000	706,000

SOLAR ECLIPSE OF DECEMBER 22, 1870.

Certain astronomical phenomena of rare occurrence and high importance for the advancement of human knowledge, have, in all civilized countries, since modern science has been cultivated, been deemed matters of national importance. Among these are total eclipses of the sun, and for many years it has been customary for the great nations to organize expeditions for the observation of them. The first total eclipse visible in this country since the formation of the Government was that of June, 1806. This was accurately observed at several points, and a valuable painting was made of it. We were not favored with another until November 30, 1834, when the moon's shadow passed over the continent from northwest to southeast. This eclipse was observed by R. T. Paine, esq., of Boston, at Beaufort, S. C. A third eclipse did not visit our country until 1860; hence, at that time this wonderful phenomenon was for most American astronomers a matter of hearsay.*

The path of the eclipse of July 18, 1860, was from Washington Territory to the northern shore of Labrador, and thence across the ocean to Spain. This eclipse was observed by expeditions organized under the Superintendent of the Coast Survey, and the results are published in the report for that year. It was also observed by the astronomers of several governments abroad, and was the first total eclipse which was photographed. In 1868, British, French, and German expeditions were fitted out for the observation of a total eclipse in India. On this occasion brilliant discoveries were made in regard to the spectrum of certain rose-colored prominences seen about the sun at such times; and these discoveries have been increasing in interest ever since. In 1869 another total eclipse was visible in the United States. It was observed by parties organized by the Coast Survey and other Government bureaus. The results were of high importance. Photographs of the whole corona were taken for the first time; the first observations were made upon the spectrum of the corona; the radial polarization of the corona was first observed with care, while the former knowledge of the subject was advanced in every direction. The results of these two

* Mr. G. P. Bond had observed the eclipse of 1851, in Sweden.

eclipses were of such importance in regard to one of the chief scientific problems of our time, the constitution of the sun, as to excite the profoundest interest throughout the world. It was felt by everybody, even casually interested in science, that the eclipse of 1870 afforded an opportunity for removing the last obscurity from the subject of the corona, such as ought not to be let slip, the more so as no other eclipse was expected to be observed during this century.* In accordance with these views the Hon. John A. Bingham, of Ohio, introduced a joint resolution, which was approved by Congress and the Executive, authorizing the fitting out of an American expedition, such as were to be sent out by Germany, by France, by Great Britain, by Italy, and by Spain, to study the phenomena of this eclipse. The late unhappy war prevented the first two nations from sparing any of their energy for this peaceful emulation, but extensive preparations were made by all the others. The American and English parties were in co-operation and afforded each other mutual aid. It is hoped that the good feeling thus engendered was not without influence beyond the circle of science. The observations of this eclipse had for their general result the triumphant vindication of the American observations of the year before, the novelty of which had made them somewhat suspected in Europe; as well as the establishment of the superior accuracy of the American lunar predictions. Some new features were observed in the corona and in the chromosphere, and other observations were multiplied. This is, however, not the place for entering upon the details of scientific proceedings, which will be given with all desirable fulness in the appendix.

With a view of selecting localities where astronomical conditions, as well as those of the weather, might be expected to be favorable for observing, Mr. Charles S. Peirce proceeded to Europe in advance under my direction, and after visiting Italy, Spain, and European-Turkey, recommended the occupation of stations in Southern Spain and in Sicily. The country east of Italy over which the track of the totality passed had the sun too low for photographic purposes. Considering the probable distribution along the line of totality of the European astronomers, I decided finally to dispatch two parties, one to be stationed in the vicinity of Xeres, in Spain; the other under my immediate personal direction, to occupy positions on the island of Sicily, in the neighborhood of Catania. In selecting observers I availed myself of such as had previous experience, which, in matters pertaining to solar eclipses, is of much importance, and whose former services in the special lines of duty assigned gave full assurance that no fact that could possibly be noted under the circumstances would be lost.

The party organized for service in Sicily had the threefold duty assigned of making measures of precision, including the determination of the geographical position, and local time of contact; of getting photographic impressions of the various phases of the eclipse and of the corona; and of analyzing the corona by means of the polariscope and spectroscope. Accompanying phenomena were also to be recorded. To improve, as much as possible, the chances of the weather, the party was spread over as large an area as could conveniently be included, a precaution which proved of great value, as may be gathered from the account of the labors of the party.

A most cordial co-operation with the party of British observers, several members of which took position at Catania, was maintained throughout our stay. While in England and on the continent, on my way to the place of observation, the opportunity was taken to procure additional instruments required for our purpose.

The party is indebted to Mr. Wilding, our vice-consul at Liverpool, and to Signor Cattaneo, Italian consul at that port, for affording facilities to pass our instruments through the Messina custom-house. Our thanks are especially due for most effective assistance rendered in receiving, storing, and forwarding our instruments, and reshipping them for New York, to our consul, Mr. F. W. Behn, at Messina, and the vice-consul, Mr. Aug. Peratoner, at Catania. We were indebted also to Professor Lorenzo Madden and Professor Orazio Silvestri, of Catania, for assistance, and to the municipal authorities for permission to use the grounds occupied by the observers.

The distribution of the party in the vicinity of Catania, and the nature of the results secured, will be briefly mentioned.

Our principal station was in the garden of the Benedictine convent of Saint Nicola, in the

* Nevertheless, the British government has sent out parties to another eclipse in 1871, in India and Australia, and three American astronomers have been invited, through the Superintendent of the Coast Survey, to join the expedition.

western part of the city—a position selected by Assistant Charles A. Schott, who determined early in December the latitude and longitude, and also the local time. L. M. Rutherfurd, esq., of New York, provided photographic apparatus for use by Mr. H. G. Fitz, optician, who was sent in charge of the equatorial, and was assisted by Mr. D. C. Chapman and Mr. Burgess, photographers. For determining time and latitude, Mr. Schott used the portable meridian telescope C. S. No. 9, and sidereal chronometer Kessel, 1287, which was rated at Washington, and checked at London, Berlin, Munich, and Naples. For local time comparisons the party is indebted to Dr. Förster, director of the Berlin observatory; to Dr. Lamont, director of the Munich observatory; and to Professor de Gasparis, director, and Mr. Fergola, assistant of the observatory at Capo di Monte at Naples.

Transits were recorded on five nights, and thirteen pairs of stars were observed for latitude; the longitude depends upon that of Naples and Munich. In order to secure accuracy, Mr. H. H. D. Peirce compared chronometer times at Syracuse with the party of observers from the United States Naval Observatory, thus verifying the determination for longitude of the respective stations. A number of chronometers were in advance rated for the use of the observers, and a small triangulation was made uniting the eclipse stations in the garden with the triangulation by Dr. Peters and Baron Waltershausen, who surveyed that vicinity previous to the year 1841. It is gratifying to note the very close accordance between the earlier astronomical determinations and those taken thirty years afterward. Time-signals, by heliotropes, were sent and received by the observers at Catania and at the Monte-Rossi station. Mr. Schott included in his series of geographical positions the three places occupied in the garden of the convent, two by the English party in charge of Mr. J. Norman Lockyer, and the other by Mr. J. H. Lane, of the office of United States Weights and Measures, who, though fully prepared for spectroscopic observations, was prevented by unfavorable weather from recording special results. The photographic party secured forty-five negatives of the sun, seventeen during the eclipse and before totality, and fourteen after it, at irregular intervals, taking advantage of breaks in the clouds. The direction of a parallel of declination was indicated by the image of a thread so adjusted before the eclipse that a solar spot might be seen as moving along the thread during the transit. Mr. Fitz operated the equatorial and timed the pictures. An attempt was made by means of an ordinary camera to secure an impression during the momentary appearance of a portion of the corona. The time of the first contact was noted by Mr. Schott, who was apprised by a pistol fired by a member of the English party, (the report by pre-concert,) indicating that Mr. Lockyer had already spectroscopically noted the approach of the moon's limb over the solar chromosphere. The dense clouds which came from the direction of Mount Etna and to the west of it defeated all attempts at observing the times of the inner contacts, and of the last contact. Mr. Schott, however, saw through a rift in the clouds a part of the corona to the northward and eastward of the sun's center for about three seconds. It appeared in sharp outline, nearly concentric with the moon's limb, of white, silvery light, extending, by estimation, to about one-third of the moon's radius. The light tint of orange-yellow, usually accompanying total eclipses, was seen about the southern and eastern horizon. The first contact, or beginning of the eclipse, as predicted from data in the American Ephemeris, was only three and nine-tenths seconds earlier than the time actually noted in observing at Catania.

My own station was about three miles north of Catania, at the villa of the Marquis di San Giuliano, whose obliging courtesy is a subject of grateful remembrance. There the weather was more favorable than at the city, and afforded a full view of the corona, the study of which was made a special object. Mr. C. S. Peirce observed with a polariscope and obtained good results. Mrs. C. S. Peirce was successful in drawing the corona, and distinctly recognized the dark rifts which have become the subject of discussion, and which were photographed by Mr. Brothers, of the British party, at another station. Farther north were stationed Bvt. Brig. Gen. H. L. Abbott, United States Engineers, Professor Roscoe, of England, and Signor Amerigo de Schio, Dr. Vogel, of Berlin, and others. Their object was to observe the phenomena of the eclipse at the greatest possible height on the southern slope of Mount Etna, for comparison with similar observations taken at stations near the sea-level. It is much to be regretted that this party was overtaken by a snow-storm, which obscured the sky, and obliged them to descend during the time of the eclipse.

A few miles to the westward and northward of Catania, at one of the trigonometrical signals on the western peak of Monte Rossi, Dr. C. H. F. Peters, of Hamilton College, Clinton, N. Y., and Sub-Assistant W. Eimbeck, selected a position for observing the eclipse. Dr. Peters had a

spectroscopic apparatus, and Mr. Eimbeck a comet-seeker. This party, also, had unfavorable weather, but succeeded in noting the times of the first contact and of the last contact—the last through thick haze. The interior contacts were lost on account of a passing hail-storm. Mr. Eimbeck also assisted Mr. Schott in recording transits and other observations at Catania.

Professor J. C. Watson, of Ann Arbor, Mich., occupied a station on the high ground near Carlentini. The weather there was favorable during the time of totality. Professor Watson made observations which resulted in two colored drawings of the corona, of unrivaled fullness of detail and accuracy. Dr. T. W. Parsons, at Syracuse, also made an elaborate colored representation of the eclipse.

It will thus be seen that my party in Sicily were distributed to the *north* of the track of total eclipse, while stations to the south of it were occupied by the party from the United States Naval Observatory. Stations on the central line were occupied by the Italian astronomers, including the Padre Secchi, Professor Cacciatore, and others.

A detailed account of the results of observations will be found in the Appendix No. 16 of the report of 1870.

I take this opportunity to mention the kindness of Henry Suter, esq., Her Britannic Majesty's vice-consul at Larissa and Volo, who, when it was contemplated to send a party to Larissa, afforded every facility for the prosecution of inquiries; and was in readiness to assist further, if it had been expedient to occupy a station near that city.

The general charge of the observations to be made in Spain was assigned to Professor Joseph Winlock, director of Harvard College Observatory, Cambridge, Mass., with Assistant George W. Dean, of the Coast Survey, as executive officer.

The party of eleven persons from the United States was organized early in October, 1870. Nearly all were scientific observers, and had been so engaged during the total eclipse in August, 1869.

Two English and one Spanish observer joined the expedition at Jerez, and it is highly gratifying that notwithstanding the unfavorable weather on the day of the eclipse, most of the observers were quite successful.

It being desirable to obtain as far as practicable in advance, information in regard to the meteorological conditions of the winter climate of Southern Spain, Assistant Dean, before leaving England, collected statistics which proved of much value in selecting the locality in Spain for observing the eclipse. Mr. Dean was cordially assisted in his inquiries by the Astronomer Royal, and by several members of the Royal Astronomical Society.

Professor Winlock, Capt. O. H. Ernst, of the United States Engineers, Professor C. A. Young, Professor S. P. Langley, Professor Edward C. Pickering, and several other members of the expedition, sailed from New York for Liverpool early in November and reached London about the middle of that month. Most of the instruments and equipments were reshipped at Liverpool for Gibraltar, arriving at the latter port near the close of November, and from thence were forwarded by steamer to Cadiz.

The information obtained from commanders and chief officers of steamers plying between England and Mediterranean ports, in regard to probabilities of weather, was confirmed by the observations of other gentlemen, who had long resided in Southern Spain. Comparison of statements showed that the prospect for fair weather on the day of the eclipse might be hoped for at points on or near the Atlantic Coast.

The geographical position of Jerez being favorable, with good facilities for transportation by railroad from Cadiz, Professor Winlock decided to make the necessary arrangements for observing the eclipse near that place.

The principal station was located about a mile northeasterly from the city, in an olive grove belonging to Messrs. Richard H. Davies and brother. These gentlemen placed their grounds and buildings at the disposal of the expedition, and their constant aid and generous hospitality to all the observers during their stay at Jerez is gratefully acknowledged.

Some delay was experienced in obtaining lumber and other materials, but all difficulties were readily met. On the 16th of December the instruments were in position, and good observations

for time and latitude were made by Assistant Dean and Captain Ernst, assisted by Mr. Henry Gannett, of Harvard College Observatory.

These observations were repeated on several favorable nights, immediately preceding the day of the eclipse, at which date the latitude and local time at the eclipse station had been well determined, completing the necessary arrangements for observing the phenomena.

The day preceding the eclipse was unusually pleasant, but about midnight clouds began to cover the sky, and in a few hours the rain fell rapidly, with a strong wind from the southwest. The prospects for success on the morning of the 22d of December were exceedingly doubtful; nevertheless, each observer continued to perfect his arrangements, hoping that before the beginning of the eclipse the clouds would open, and give an opportunity to all to complete the observations so earnestly desired. These hopes were in the main realized.. The time of the "*first contact*" was successfully recorded by Assistant Dean, and a few seconds later the photographer of the expedition, Mr. O. H. Willard, of Philadelphia, obtained a good photograph of the sun. During the progress of the eclipse Mr. Willard, with the assistance of Mr. J. Mahoney, took fourteen photographs of the eclipse, one of them exhibiting very satisfactorily the coronal structure during totality. The equatorial telescope used by the photographer has a focal length of about seven feet, with an aperture of six and a half inches, corrected for actinic rays. This instrument and several others for the service were furnished by Professor Winlock. The photographic telescope used by Mr. Gannett had a focal length of about thirty-five feet, with an aperture of four inches. This telescope was firmly adjusted in a horizontal position, receiving the solar rays from a movable heliostat near the objective. Mr. Gannett obtained five photographs in the course of the eclipse, but owing to partial obscuration by clouds they were not entirely satisfactory.

The time at which each photograph was taken was recorded by the chronograph.

Spectroscopic observations upon the sun were made by Professor Winlock with two prisms, attached to a five and a half inch achromatic telescope. Professor Winlock had devised a very complete apparatus for recording the positions of the lines seen in the spectroscope as rapidly as the observer could point upon them, and with a precision equal to measurements with a micrometer. Before leaving America, each spectroscope for use in Spain was provided with this apparatus, which consisted essentially of a steel point or graver, movable by a micrometer-screw, so that in pointing upon any line seen in the spectroscope the exact position of the line would be recorded upon a small silver plate, when the observer pressed the graver key. Professor Winlock observed a faint continuous spectrum, without dark lines. Of the bright lines, the most conspicuous was Kirchoff, 1474, which was seen in all the spectroscopes.

Professor Young, of Hanover, N. H., used a new spectroscope, recently designed by him, and constructed by Messrs. Alvan Clark & Sons, of Cambridgeport, Mass. It has a train of six prisms of heavy flint glass, each two and one-fourth inches high, and having a refracting angle of fifty-five degrees. A seventh *half-prism* follows, on the back of which is cemented a right-angled prism, by which, after two total reflections, the light is sent back through the upper part of the same train of prisms until it reaches the observing telescope. A description of this instrument has been published by Professor Young in our scientific journals.

With this spectroscope attached to the Dartmouth College equatorial, having a focal length of nine feet, and aperture of six and a half inches, Professor Young was enabled to watch the occultations of the protuberances, and announce the approach of the moon several seconds before the "*first contact.*" With the slit of the spectroscope placed tangentially at the moment of obscuration, the field of the instrument was *filled with bright lines.*

Mr. Pye, a young gentleman who assisted Professor Young, saw this with a spectroscope of one prism.

Mr. Abbay, of Wadham College, Oxford, also observed with a spectroscope, and his results were soon after published in the English journals.

Professor Langley, of Allegheny, Pa., observed the structure of the corona with a grand achromatic of four inches aperture, and a power of about one hundred and fifty. He reports that, on the closest scrutiny of the part nearest the sun, nothing was seen but a nearly uniform diffused light, except that one dark ray in the field was noticed to be absolutely straight, and nearly radial.

The outline of the corona was roughly quadrangular, the larger diagonal making an angle of nearly forty-five degrees with the vertical. Professor Langley also used a Savart's polariscope, which was attached to a small telescope of one and a half inches aperture. During totality the bands were distinctly seen on the corona, and were brightest where normal and tangent to it. As the polariscope was slowly rotated, no marked change of their brightness was seen during the whole revolution, and they presented the appearance and characteristics of radial polarization.

Captain Ernst occupied an elevated station about half a mile northwest of the principal eclipse-station. His observations were upon the general appearance of the corona and landscape during totality. Mr. Gordon, who resides in the vicinity, was at the same station, and made an excellent sketch of the corona.

Professor Pickering, of Boston, also occupied the station last mentioned, and successively used an Arago polariscope, one of the Proymowski form, and a Savart, and obtained similar results with each, which indicated the radial polarization of the corona.

The light covering the moon's disc was observed to be polarized throughout in the same plane, and the observations showed that the Arago and other polariscopes dependent on color, were sufficiently delicate to determine the plane with accuracy.

Mr. Ross, at the same station, used a modification of the Bunsen photometer, and obtained several accordant measurements, showing that the light was about equal to that of a candle burning at a distance of two feet.

While the preliminary observations at the "*Olivar station*," at Jerez, were in progress, a meridian-line, one hundred and forty-six metres in length, was established and carefully marked with stone posts by Assistant Dean.

With the friendly co-operation of Captain Pujazen, director of the San Fernando Observatory, arrangements were also made for exchanging clock-signals by telegraph, for the purpose of determining the longitude of the Olivor station, but the continual stormy weather prevented the execution of this work. Assistant Dean acknowledges the valuable assistance rendered by Capt. José S. Montop, chief of the Spanish Coast-Survey, who, in addition to other data furnished, kindly offered to connect the American eclipse-station by triangulation with the Spanish survey.

Captain Montop's observations place the longitude of our eclipse-station, at Jerez, 4′ 55″.3, or $19^s.7$, *east* of the observatory at San Fernando, which would give for the Olivar station approximately $4^h\ 43^m\ 42^s.1$ *east* of Washington.

The expedition was successful, and results of great value have been obtained. In the appendix (No. 16 of the report of 1870) will be found the details noted by the several observers.

MAGNETISM.

Observations made by the field-parties for determining the magnetic declination, dip, and horizontal intensity will be mentioned in connection with other processes of the survey, to which the observations were incident in several of the coast-sections.

At the magnetic station on Capitol Hill, in Washington City, Assistant Charles A. Schott recorded, in June, a complete series, and from his observations deduced the declination, dip, and intensity. His successive yearly results make parts in the discussion of the secular variation at Washington City.

In several instances, within the year, observers not connected with the survey have availed themselves of the means afforded at the standard station for testing and comparing their magnetic instruments. Those now in use in the Arctic expedition, under Captain Hall, were adjusted by the assistance of Mr. Schott. The instruments used by the exploring party of Lieutenant Wheeler, in the region of the Colorado River, were tested at the same station. Assistant W. H. Dall, now on the coast of Alaska, is provided with the means of making reliable magnetic observations; all the instruments for use under his direction having been compared at the station on Capitol Hill just previous to his departure for the Aleutian Islands.

Late in November, when the iron steamer Hassler was about to sail from Boston, Assistant Schott, at my request, made elaborate observations for testing the magnetic condition of the vessel, and for determining the heeling error, and such other data as might be requisite for the effective

use of the compasses in steering. The application of instruments provided as tests, and which were left on board, was fully explained by Mr. Schott. As practical illustrations he measured the dip, the ratios of the horizontal and vertical intensities, on shore and on the vessel, and the deviation of the standard compass for the heading of the vessel at the time. Lieutenant Murray S. Day, of the *Hassler*, assisted in these observations. The records and manuals on the deviation of compasses on board of iron ships were left in the charge of Dr. Hill, who accompanied the hydrographic party in the *Hassler*.

OBITUARIES.

The year 1871 has been unusually marked with sadness to us by the premature death of five of the younger men attached to the Survey, each of whom was known among his associates and to myself as of the most active and useful in his grade.

To the hydrographic division the change thus wrought has been especially severe. The record of deaths includes one of its most trusted members, and two thoroughly-trained aids, who had given great promise of efficiency in hydrographic pursuits.

Sub-Assistant William W. Harding died of typhoid fever at Philadelphia on the 25th of September, suddenly closing, in the midst of special adaptation and earnestness in duty, a period of twelve years of service. At the date mentioned his party was engaged in hydrographic work on the coast of New Jersey. Summer and winter, for several years previous, he had unremittingly pushed similar duty to complete the survey of the branches of the Chesapeake Bay, himself tracing the shore-lines, and in large results giving sure evidence of patience, energy, and skill. He had in full measure all the qualities desirable in his profession. In him a cultivated mind was ready at any time to be enforced by a strong will, and the utmost which could thus be done in any direction he had of himself subordinated to the interests of the work committed to his charge.

The social qualities of Sub-Assistant Harding endeared him to all in the Survey, and to a large circle of friends outside of its membership.

Arthur F. Pearl and *George W. Bissell*, two hydrographic aids of great merit, were drowned near Apalachicola, Fla., on the 26th of February, together with four men of the party on service in that vicinity. The disaster resulted from the upsetting of their sail-boat in a very sudden squall of wind on their return to the anchorage of the schooner Silliman, which was about four miles off, after having attended church at Apalachicola.

These aids were young men highly valued for their confirmed moral worth, and for industry and attention in the performance of duty. Both were good sailors, and, besides being well qualified in other respects, they had evinced strong inclinations toward the hydrographic service. In that branch their thorough training had been strongly seconded by their own native energy and readiness to encounter any dangers incident to the course of duty.

During several seasons the senior aid served in Chesapeake Bay, in the party of Sub-Assistant Harding, whose subsequent untimely death has been already mentioned. For the winter service of 1870, Mr. Pearl, at his own request, was transferred to the warmer air of a station on the Gulf coast, his over-exertion in the Chesapeake hydrography having brought on hemorrhage of the lungs. His amiable companion, Mr. Bissel, had been previously associated with several hydrographic parties in different sections of the Atlantic coast.

Harry S. Hein, junior clerk in the office of the disbursing agent, died at his home in Georgetown, D. C. on the 17th of September, having just passed the twenty-first year of his age.

Under the eye of his father, and by implicit filial obedience greatly endeared, this estimable young man recently entered upon the discharge of duties pertaining to the accounts of the Survey. He was then robust and without any symptom of the rapid decline which, after a short illness, terminated in death. The break thus made in a loving family-circle strongly moves our sympathies, and our regret for the loss to the service of so much promise. In the short period of his service, Mr. Hein had won regard by his amiable deportment and by readiness in business.

John H. Diggs, colored messenger, died of consumption, at his own house in Washington, on the 12th of July, aged thirty-six years. Before the close of boyhood he came into service in the Coast

Survey Office, and his intelligence and tact, shown in years of personal attendance on the Superintendent, kept for him the unvarying esteem of the late Professor Bache. The same qualities soon won my personal regard. I valued him also as a man who had ripened in knowledge by constant devotion to the interests of his official superior.

A few years ago, when stricken with pulmonary weakness, John was assigned to such service at the Office as least taxed his vital strength. The progress of disease was not lessened, yet his duties were performed with but few intermissions until a few weeks before his death.

PART II.

In this part of the report will be given short abstracts of the work done by the several parties. The notices will be, as heretofore, arranged in geographical order, beginning on the Atlantic with the coast of Maine, and closing with mention of work done on the coast of Texas. On the Pacific side, the most southern site of work will be mentioned first, and others in geographical order going northward, the notices closing with mention of arrangements made for hydrographic service on the coast of Alaska. Field-work at points intermediate between the Atlantic and Pacific will be placed in conformity with the longitude of the sites.

Hence reports on the determination of geographical positions in Ohio, Illinois, Kentucky, and Missouri will be classed with abstracts of work done on the coast of the Gulf of Mexico. The statements, concise as possible, will be limited generally to mention of the sites, names of the assistants employed, and brief mention of statistics. Before entering upon these details, a few remarks are due to the distinctive branches of the work.

The progress of the triangulation on the Atlantic and Gulf coasts during the past year has fully realized the views which were embodied in my estimates of September, 1870. No plan, however, in regard to special localities, made out a year in advance, can be adhered to in every detail. Unforeseen emergencies arise, and calls are made for special information. To such contingencies the extended operations of the survey have been subject during recent years in the interests of commerce and for other public uses. Hence, while the triangulation has not been continued at every locality proposed in the estimate referred to, other sites, and sometimes other duties, have been substituted, according to the necessities of the service. In some cases, parties have been concentrated, where immediate results were advisable.

Including the usual reconnaissance and astronomical work inseparably connected with the triangulation, thirteen parties have been engaged in the course of the year at twenty-seven sites on the Atlantic coast and Gulf of Mexico. This is exclusive of other branches, in one or other of which parties have operated within the year on the borders of all the seaboard States of the Union, excepting Delaware and Alabama.

In accordance with the recommendation contained in my preliminary report of September, 1870, a small appropriation was made by Congress, at its last session, for commencing the geodetic connection between the Atlantic and Pacific coasts, and for the determination of points in any of the interior States which may require them as the basis for State surveys, or for the construction of State maps. The expenditure of part of that small sum has already revealed a considerable error in the hitherto accepted geographical position of so prominent a point as Columbus, Ohio. It is certain that any expenditure which may be made for this purpose will soon be repaid to the General Government by the more accurate information thus acquired in regard to distances, or the length of post-routes, upon which contracts for the postal service are principally based. By the 1st of July, at which date the appropriation became available, applications had been made by the governors of New Hampshire, Ohio, Indiana, and Missouri for the determination of geographical positions within the limits of their respective States. Accordingly several parties were assigned, and have been engaged in this duty and in the geodetic connection during the past five months. Statements in detail of their labors and results will be found further on in this report. Near the end of November last, the governor of California made a similar request.

On the 1st of December, 1870, a communication was received from the Hon. G. C. Walker, governor of Virginia, applying, in conformity with a joint resolution of the general assembly of that State, "for the assignment of a competent corps of surveyors to the duty of ascertaining and locating the true boundary-lines between the State of Virginia and the States of Maryland, North Carolina, and Tennessee." On the 15th of January last a somewhat similar application was made by the Hon. Oden Bowie, governor of Maryland, in terms as follows: "By an act of the general assembly of Maryland, of 1868, a commission was appointed to meet a commission to be appointed by the State of Virginia, to settle and adjust the boundary-line on the eastern shore of the Chesapeake Bay, between the States of Virginia and Maryland. It is particularly desired that the survey required in this work should be made by the most competent and experienced corps of surveyors. I, therefore, on the part of Maryland, apply to you for the assignment of such a corps from those engaged in the Coast Survey."

These applications were referred to the Department, with a recommendation that they should be favorably considered. The approval of the Secretary of the Treasury was given in February, with the understanding that the operations of the party detailed should be confined to the work of ascertaining and locating the "true boundary-lines between Virginia and Maryland," and "that all proper expenses incurred be paid by the States interested." In pursuance of this authority, Richard D. Cutts, esq., the assistant in charge of the secondary triangulation, was requested to take general charge of the proposed surveys; to meet the joint commission, and, after consultation, to make the necessary arrangements for the prompt execution of the work. It was not, however, until the 17th of November last that a meeting of the commission was called at Crisfield, Md., to which point Mr. Cutts proceeded a few days afterward. A majority of the Maryland commissioners not being in attendance, and the season for field operations being unfavorable, considering the delay that must occur before a surveying party, at the short notice given of the meeting, could be organized, the surveys were postponed. The commission adjourned to meet in May next.

In a general review presented by Assistant Cutts, I recognize the special advantage of his services in the study of details connected with the secondary triangulation. To him is due also the recognition of valuable suggestions for commencing the determination of points in the interior, the plan for which was settled early in the summer by a reconnaissance in the Western States, in which I was accompanied by Mr. Cutts. Previously he had completed the computations resulting from an extended series of observations and measurements for determining the heights of geodetic stations in Section II. Late in June, Assistant Cutts organized his party and prosecuted field service near Mount Holly, mention of which will be made in its place in the body of this report. In the course of the season he reviewed the progress of several of the triangulation parties in the field, including those engaged on Lake Champlain, and there made arrangements for extending the triangulation northward to the United States boundary, by parties available for that service from other sections after mid-summer.

In field topography, under the general charge of Assistant H. L. Whiting, satisfactory progress has been maintained.

As most of the important points along the Atlantic coast have been covered by local surveys, the basis is well laid for systematic operations in the execution of general progress work. Special attention has also been given and special force assigned to the filling up and completion of various gaps in work which earlier demands for the survey of particular localities made unavoidable. During the current surveying year detached surveys have been united on the coasts of Florida, South Carolina, Virginia, Rhode Island, and Maine, so that the coast topography is now continuous from below Saint Augustine, Florida, to Broad River, South Carolina; and from Beaufort Harbor, North Carolina, to Penobscot Bay, on the coast of Maine. The particular gaps in former work which have been closed during the current year are as follows: Nassau Inlet, Florida, between Savannah River and Broad River, South Carolina; on the sea-coast of Virginia near Cape Charles; on the lower islands in Narragansett Bay, Rhode Island; between Saco River and Richmond Island, and in the upper reaches of the Kennebec River, Maine.

In general progress work the coast topography has been carried forward on the Gulf coast of Florida and Louisiana, on the interior shores of Pamplico Sound, North Carolina, and in the resurvey

of the sea-coast of New Jersey, made necessary by the changes in its sandy inlets and beach formation. On the coast of New England needful resurveys have been made on the outside coast of Rhode Island; and active operations have been continued in Penobscot Bay and Mount Desert Bay, on the coast of Maine.

The survey of the topography of the northern part of Lake Champlain has been completed under the general direction of Assistant Whiting. On notice and application from the State board of harbor commissioners of Massachusetts, in reference to certain changes on the sea-coast of the State, special surveys have been made of the harbors of Edgartown, Vineyard Haven, (formerly Holmes' Hole,) and Nantucket. The resurvey at Edgartown Harbor reveals one of the most important physical changes which has occurred on this section of the coast for many years, and the change involves the destruction (unless measures are taken to preserve it) of one of the most valuable harbors of refuge on the Atlantic sea-board. The subject of these changes, with the details of results, will be treated in reports from the officers who made the special surveys.

Besides the charge of details for plane-table work and the inspection of such field-sheets as required revision, Assistant Whiting has retained his advisory connection with the State board of harbor commissioners for Massachusetts. This, although incidental, has become an important and arduous service, and has maintained a desirable relation between the General Government and the Commonwealth of Massachusetts in the improvement and preservation of harbors on the extensive and important sea-board of this State.

The hydrographic inspector, Capt. C. P. Patterson, has provided as usual for the transportation of the field parties needing vessels, and for the service afloat. The relation is direct between the field-work and hydrography, and both, for the earliest productive uses, are dependent on the condition of work in the drawing and engraving divisions of the office. Hence the allotments for hydrographic service are made to supplement the field-work, and, when practicable, to complete the charts that may be furthest advanced toward publication. Among the details in the care of the hydrographic inspector are the notes of dangers, and sailing directions for charts, the correct marking on them of buoys and other aids to navigation; inspection of the sheets when marked with soundings, and the selection from all the soundings of such as will represent without needless repetition the hydrographic features of places where surveys have been made.

To the ordinary duties and responsibilities of the hydrographic inspector have been added within the year others growing out of the necessity for replacing vessels that have worn out in the service.

The details of work on the Pacific coast will be given in the body of the report, under the head of Sections X and XI. I am specially indebted to Assistant George Davidson, who makes his intimate knowledge of that coast effective by suggestions, for placing the several parties to the best advantage for the public service. The operations of his own field party will be stated in geographical order in the two sections. Assistant Davidson made available at the earliest moment the telegraphic lines recently passed along the western coast, for the determination of longitude, and has thus, and by latitude observations, largely added to our list of reliable geographical positions. The frequent recurrence of his name in Appendix No. 1, which shows the distribution of parties during the year, is evidence of characteristic energy and devotion to the public welfare. For the Coast Pilot of California, Oregon, and Washington Territory, written by Assistant Davidson, and already published in several editions, he collected further materials while passing to and fro within the present year between San Diego and Olympia.

In addition to regular duties Mr. Davidson made a thorough comparison of the working weights and coin weights, and tested the balances now in use in the branch mint at San Francisco. This examination was undertaken at the special request of the Treasury Department. The necessity for such accuracy as can be maintained only by rigid examination, repeated from time to time, will be understood on mention of the amount coined, which, at San Francisco, rises to nearly thirty millions of dollars in a single year.

Under the head of Sections, beginning at the northeastern boundary on the coast of Maine, will now be given brief reports of each of the separate operations of the year. A condensed view of the field service, conformable in arrangement to the several abstracts, is shown in the Appendix No. 1.

SECTION I.

ATLANTIC COAST OF MAINE, NEW HAMPSHIRE, MASSACHUSETTS, AND RHODE ISLAND, INCLUDING SEA-PORTS, BAYS, AND RIVERS. (SKETCH No. 2.)

Hydrography southeast of Moose-a-bec Reach, Me.—Soundings which were made last year developed the roadstead known as Moose-a-bec Reach, and also the hydrography of the approaches to it east and west. In order to complete the survey of the vicinity a party was sent in July in charge of Sub-Assistant Horace Anderson, with the schooner *Silliman*. The outer ledges in the southern and southeastern approach were defined by soundings in the course of the month of August. Mr. Anderson then completed the hydrography in the vicinity of the larger islands, and added such details as were needed to the three sheets of the survey of last year. Many dangerous sunken ledges were developed by the supplementary soundings. The statistics of this work, which was closed on the 16th of September, will be included under the next head.

Hydrography of Prospect Harbor, Me.—This hydrographic survey occupied the party of Sub-Assistant Anderson from the 18th of September until the 20th of October. An accident to the boiler of the small steam-launch *Sagadahoc*, which was in the service of the party, occurred a few days after the soundings were taken up, and rendered the vessel useless for the remainder of the season. The hydrography was of necessity prosecuted with the schooner *Silliman*. Among the developments at Prospect Harbor were included the dangerous ledges which lie about a mile south of the entrance. Sub-Assistant Anderson was aided in this section by Messrs. C. H. Van Orden and E. B. Pleasants. The statistics subjoined include the work done in the approaches to Moose-a-bec Reach:

Miles run in sounding	340
Angles measured	4,307
Number of soundings	18,827

In the early part of the year Mr. Anderson conducted a hydrographic party in Section VII, as will be further mentioned under that head. He is now making preparation to return to the same site of work.

Topography and hydrography of Somes' Sound, (Mount Desert Island,) Me.—The survey of this harbor was made in the course of the summer by Assistant J. W. Donn with a party in the schooner *Scoresby*. Southwest Harbor, an indentation on the western side of Somes' Sound, and all the islands in the vicinity were included, and are represented on the resulting chart. (See sketch No. 18 in report for 1870.) The topographical details, as usual in this section, are intricate, but permanent in character. Hence the plane-table sheets, which year by year pass into the archives, may be expected to represent for a long time to come the surface features of this part of the coast of Maine. The details presented by Mr. Donn truly depict the ground passed over by his party. Statistics are subjoined of the field-work and soundings which were completed in October:

Miles of shore-line surveyed	104
Miles of roads	37
Area of topography, (square miles)	28
Miles run in sounding	467
Angles measured	3,841
Casts of the lead	20,583

Tidal observations were carefully recorded as usual while the soundings were in progress.

Sub-Assistant L. B. Wright was attached to the party in the *Scoresby*. He had previously assisted in the party in Section III, where Mr. Donn is now in readiness to resume field-work. Mr. Wright is under instructions to conduct a hydrographic party in Section IX.

Topography of Seal Harbor, Me.—This harbor of refuge is a recess in the southeastern part of the Fox Island group at the entrance of Penobscot Bay. The plane-table work recently turned in by Sub-Assistant H. M. De Wees completes the topographical survey of the islands, including the shores of the harbor, of which the area is about three and a half square miles. The water-

space is greatly crowded with small islands and ledges, and these are such that the harbor is not navigable at low water.

Mr. De Wees resumed field-work in this section on the 5th of August, and closed the survey on the 19th of September. He had been previously employed in Section VII. The statistics of the sheet showing the vicinity of Seal Harbor are as follows:

Miles of shore-line traced	27
Miles of roads	$3\frac{1}{2}$
Area of topography, (square miles)	5

A tracing from the plane-table sheet was furnished to Assistant Webber, who, being then engaged in the general hydrography of Penobscot Bay, incidentally developed the ledges in Seal Harbor. Sub-Assistant De Wees has been assigned to service for the winter on the Gulf of Mexico.

Topography of Deer Isle Thoroughfare.—The plane-table survey of this pass between the large islands which bound Isle au Haut Bay on the eastward, has been made by Assistant W. H. Dennis. As usual in the work of this vicinity, the shores of all the adjacent small islands were traced at low water, and many ledges were defined. Field-work for the season was closed on the 3d of November.

On the western side of Penobscot Bay, Assistant Dennis completed the topographical survey of the Muscle Ridge Islands, where the work of his party was commenced on the 10th of July. He was aided in the service in this section by Mr. A. P. Barnard.

The statistics of the two plane-table sheets are subjoined:

Miles of shore-line traced	45
Miles of roads	2
Area of topography, (square miles)	18

Field-work previously done by the party of Mr. Dennis will be mentioned under the head of Section VI. He is now completing arrangements to resume plane-table duty on the coast of South Corolina.

Topography of Penobscot Bay, Me.—In the middle of July Assistant F. W. Dorr resumed plane-table work near Camden, Me., and extended the topography of the western side of Penobscot Bay toward Belfast. Assistant C. T. Iardella at the same time worked on the shores of Belfast Bay with a separate plane-table. Mr. Dorr's sheet at its upper limit includes Knight's Point and the details southward to Spring Brook in the vicinity of Camden. Westward it takes in part of Megunticook, one of the Camden Hills, and shows the surface features to an average breadth of about two miles in going northward. Knight's Point on this sheet is an important landmark for vessels bound up Penobscot Bay. The harbors or roadsteads of Lincolnville and Duck Trap, which are slight indentations, appear on the lower sheet of this survey. These have no protection from bay winds, but the mouth of Duck River offers a small inner harbor at high tide for vessels of light draught. At low tide the channel is nearly dry.

Along this part of Penobscot Bay the topography is much broken. The elevations are high, and being shore characteristics they will be represented upon the final charts. On the topographical sheet of Assistant Dorr heights are shown ranging from four hundred and fifty to about fourteen hundred feet. For the tertiary triangulation needed in this part of the work, signals were set up under the direction of Mr. Dorr by the Aid, Mr. W. E. McClintock, who subsequently occupied the stations with a theodolite. Some points thus determined had been previously fixed by means of the plane-table, and proved to be closely coincident, showing the completeness of the projections sent from the office for plane-table work. Above Knight's Point Assistant Dorr traced the shore-line on a second sheet, to provide for the advance of the hydrographic party of Assistant Webber, leaving the details for completion in another season.

From the northern limit of the plane-table sheet last mentioned, Assistant Iardella extended the survey northward to include the shores of Belfast Bay. By the close of September he had completed the topography near the town, and then extended the survey eastward around Moose Point, making the work conformable with that of Assistant Dorr. By means of points already

determined the survey about Belfast can be readily joined next season with the detailed topography near Camden. The statistics of the two parties are as follows:

Miles of shore-line surveyed	33¼
Miles of rivers and streams	83
Miles of roads	136
Area of topography, (square miles)	32

The field-work of Mr. Dorr, here described, was suspended on the 13th of October. A very large area was mapped by the same party in the preceding winter, mention of which will be made under the head of Section IV. Assistants Dorr and Iardella are now making preparations to resume field-service in that section.

I visited the camp of Mr. Dorr, near Lincolnville, Me., in August last, and took pleasure in noticing its neatness and economy. He is energetic in the field and by forecast saves time. I could readily identify the details of his work as faithful representations of the features along the Penobscot Bay. The details then on the plane-table sheet of Assistant Iardella showed also untiring patience to secure accuracy. Mr. Iardella kept the field until the middle of November, and then, together with Assistant Dorr, proceeded to topographical duty in Section IV.

Topography of Isleboro, (Penobscot Bay,) Me.—The survey of last year by Assistant A. W. Longfellow included the islands in the western part of Penobscot Bay, below Isleboro, and also the lower part of that island, of which the total length is about eleven miles. In the latter part of May plane-table work was resumed at the limit reached last season. From thence Mr. Longfellow continued the detailed survey northward, and included the entire area of Isleboro. As usual, all the islets and rocks in view are represented on the topographical sheets. The field-work was completed on the 16th of October.

In August I witnessed with great satisfaction the earnestness of Assistant Longfellow in the prosecution of this survey. He was efficiently aided by Mr. Joseph Hergesheimer, on whom devolved, toward the end of the season, the completion of the work, in consequence of the serious illness of the chief of the party. Mr. Hergesheimer is now on duty in Section VIII, where he was also engaged during the preceding winter.

Hydrography of Penobscot Bay, Me.—The hydrography of Penobscot Bay has been extended northward from its previous limit by the party of Assistant F. P. Webber, working with the steamer Endeavor. Soundings were taken up in July at the southern end of Isleboro. In the course of the summer the work was extended to the northern end of that island, developing Gilkey's Harbor, Bounty Cove, the channel between Isleboro and the main, and the eastern part of Penobscot Bay to Cape Rosier.

On a second hydrographic sheet Assistant Webber plotted soundings made by his party in Seal Bay, a harbor of refuge to the eastward of Long Island, in the Fox Island group, at the entrance of Penobscot Bay. A small rock, very dangerous to vessels entering from the eastward, was determined in position near the Fox Island thoroughfare.

Before taking up work north of Camden, Mr. Webber examined the bar at Tennant's Harbor, and forwarded to the office some additional soundings.

The statistics of the hydrographic work are subjoined:

Miles run in sounding	1,092
Angles measured	7,189
Number of soundings	54,881

Messrs. D. B. Wainwright, S. N. Ogden, and C. S. F. Hoffman were attached to the party in the *Endeavor*. Under Sections VI and VII reference will be made to the previous operations of Assistant Webber. He is now prosecuting hydrographic duty in Section V.

The arrangements for work in the party of Mr. Webber, and the judgment shown in prosecuting the hydrography, were subjects of special gratification when I visited his party in August in Penobscot Bay. Operations were continued until the 17th of October.

Topography and hydrography of the Androscoggin River and Cathance River, Me.—The survey by Assistant C. H. Boyd in this Section develops the water-communication between Brunswick, on the Androscoggin, and Bowdoinham, at the head of navigation on the Cathance River. Plane-

table work was commenced on the 24th of July. Some additional points needful in extending the survey on the western side of Merry-Meeting Bay were determined by triangulation. In that service Mr. Boyd occupied six stations with the theodolite. The topography includes both shores of the Androscoggin up to Brunswick, and the neck of land between Merry-Meeting Bay and Bowdoinham, the road joining the two towns, and, intermediate between them, the course of Muddy River. As usual, where the water-level is subject to considerable change, the plane-table sheets are marked with high-water and low-water shore-lines. Current observations were made in the rivers, and the tides were carefully recorded. The soundings in the two rivers include the navigable parts and join with work previously completed in Merry-Meeting Bay. A summary of the statistics is appended:

Signals erected	9
Points determined	7
Miles of shore-line traced, (low water)	48
Miles of roads	31
Area of topography, (square miles)	16
Casts of the lead	12,377

The two tidal stations were eight miles apart. Between them a line was run with the level to determine the plane of reference for the two tide-gauges. Mr. W. I. Vinal aided in the field-work until the 4th of October, when he took charge of a hydrographic party, the operations of which will be mentioned in the next section of this report.

Assistant Boyd completed the field-work near Brunswick in the latter part of October and then made preparations to resume field-service in Section VIII, where his party had been engaged in the preceding winter.

Sailing directions for the coast of New England.—The duty of preparing sailing directions for the coasts of Maine, New Hampshire, and Massachusetts has been continued by Assistant J. S. Bradford. In addition to this work, Mr. Bradford was directed to make a final examination of Casco Bay, including the approaches to Portland, in advance of the intended issue of a chart which will embrace the waters between Cape Small Point and Cape Elizabeth. The examination was laborious, owing to the great number of ledges and shoals to be examined, but Mr. Bradford successfully verified the hydrography between the two points named.

The party in the schooner Joseph Henry also surveyed the approaches to Saco River, including Winter Harbor and the Pool, and resurveyed the harbors of Cape Porpoise and Stage Island. The sailing directions heretofore used were revised and such additions and alterations were made as had become necessary. These were due, in some cases, to changes in the buoys, and in others to developments made by the soundings of this season.

Much of the service by this party was necessarily office-work. Forty-three ledges were examined, including fifteen which had not been previously described. The statistics are as follows:

Miles run in sounding	63
Angles	288
Number of soundings	6,571

The report of Assistant Bradford was accompanied by sailing directions for all the harbors between the Damariscotta and Boston.

Operations on the coast of New England were closed on the 1st of November. The vessel was then laid up at Cousin's Island in Casco Bay. Mr. E. H. King served as aid in the hydrographic party in this section. Assistant Bradford had been previously engaged in Section VIII, as will be further mentioned under that head.

Topography of Saco Bay, Me.—The plane-table work required to fill a gap in this part of the survey of the coast of Maine was resumed by Assistant Hull Adams in July at a point about three miles north of Saco River entrance. Going northward and eastward the topography was continued to Spurwink River, where it now joins with the detailed survey of the vicinity of Cape Elizabeth. Last season the mouth only of Saco River was included in the plane-table survey. In the work of this year the topography of the banks of that river was mapped, and also the vicinity of Saco and Biddeford. The field-work closed there on the 20th of November. To the northward the details include the roads along Old Orchard Beach, the lower reaches of Little River, and

Scarborough River; Prout's Neck and the beach beyond; and the islands and rocks in the vicinity of Saco Bay.

Assistant Adams was aided by Mr. J. N. McClintock until October, when the services of the aid were required in Section II. He rejoined the party, however, at the end of that month and completed the survey of the Saco River.

The statistics of the season are as follows:

Miles of shore-line surveyed	70
Miles of outline of shoals and marsh	27
Miles of roads	40
Area of topography, (square miles)	18

After turning in the plane-table sheet of the vicinity of Saco, Sub-Assistant McClintock was assigned to duty in Section VII.

Geodetic points in New Hampshire.—In compliance with the application of the governor of New Hampshire for the determination of points for the topographical and geological surveys in that State, under authority given to the Superintendent by the proviso attached to an item of the last appropriation by Congress, instructions were given authorizing Prof. E. T. Quimby, of Dartmouth College, to commence the work in July, when the appropriation became available. The operations were arranged to accomplish the particular object desired, as well as to facilitate the progress of the geodetic work for the survey of the coast, and for that of Lake Champlain. With this double object in view, he was directed to start from the established base, *Monadnock–Unkonoonuc*, to lay out a scheme of secondary triangles in the direction of the lake; to determine such tertiary points as might be most available and useful for local surveys; and to provide proper bases for the continuation of the triangulation to the northward and southward whenever needed, the whole to constitute a thorough reconnaissance for the extension of the primary triangulation to our frontier on Lake Champlain.

In accordance with his instructions, Professor Quimby took the field on the 1st of July and spent that month in reconnaissance and in the erection of signals at the points to be occupied as secondary stations. These stations were ten in number, as follows: Stoddard Heights, Pollard's Mount, Hartwell Hill, Lovell's Mount, Mount Kearsarge, Stewart's Peak, Sunnapee Mount, Rattlesnake Hill, Crotchet Mount, and Mason's Hill. Signals were also set on Monadnock and Unkonoonuc.

On the 1st of August the observing party was organized and the measurement of horizontal and vertical angles was commenced at Crotchet Mount, in Hillsborough County. During the month of August the aid and one man were employed in erecting tertiary signals at Lyndeborough Pinnacle, Pack, Monadnock, Barnett Mount, Duncan Hill, Bald Hill, Nelson Pinnacle, Bacon Ledge, Tuttle Hill, Hedgehog Hill, Deering Pinnacle, Crany Hill, Cochran Hill, and Mine Hill. Between the 1st and 18th of the month observations were made on the secondary and tertiary signals visible from Crotchet Mount, as well as upon a number of church-spires and other prominent objects. Professor Quimby reports that during this time only six days of good weather permitted observations.

On the 19th the party moved to Mason's Hill for the purpose of making at that station the observations required to complete the parallelogram with Monadnock, Crotchet, and Unkonoonuc. This was accomplished by the 29th, not, however, without the same experience of haze, clouds, and fog, as at Crotchet.

On the 29th of August the station on Stoddard's Heights, in Cheshire County, was occupied. Professor Quimby succeeded by the end of the month in measuring the angles at that point belonging to the triangles around Crotchet, and in thus obtaining the latitudes and longitudes of several new points.

The period having arrived for the return of Professor Quimby to his duties as professor of mathematics and astronomy at Dartmouth College, the party was discharged on the 1st of September. The instruments and camp equipage were then stored at Hanover.

During the short season of two months signals were erected and observed upon in nineteen townships of the State. The statistics of the work executed are as follows:

Secondary angles observed	13
Tertiary angles observed	58
Vertical angles observed	12
Number of measurements	1,637

In reference to the determination of points for the special benefit of the State, Professor Quimby suggests a plan for the erection of tertiary signals which would reduce the expense, and, at the same time, interest the people in the work.

He proposes to issue, in the form of a printed circular, a minute description of the signal, of the method of setting it, and a form for describing the station, and to send these circulars to the authorities of the different towns, with a view to induce them, at the expense of the town, to erect, under the supervision of the assistant conducting the observations, such tertiary signals, and at such points as he may think advisable.

Longitude observations at Cambridge, Mass.—Under separate heads in Section VII of this report, mention will be made of longitude determinations at Cleveland and Columbus, in the State of Ohio; and at Falmouth, Oakland, and Shelbyville, in the State of Kentucky, where stations were occupied for observing the total solar eclipse which occurred in August, 1869.

During autumn of the present year, Prof. Joseph Winlock, director of the Cambridge Observatory, was in communication with the observers in Ohio and Kentucky, and exchanged time-signals with them severally by telegraph for the respective longitude determinations. It is gratifying to refer to the steady and useful co-operation of the Western Union Telegraph Company in affording, free of cost, the facilities for exchanging clock-signals between distant stations. The work is done at night, and after the telegraph-offices are closed for business. Nevertheless, much of the success recorded in our longitude determinations has been due, beyond the use of the lines, to the assistance cheerfully given by the officers and operators of the telegraph company. For the observations required at the western stations the wires in each case were connected with Cambridge Observatory, so that time-signals might pass directly between Professor Winlock and each of the observers in Ohio and Kentucky.

Edgartown, Nantucket, and Vineyard Haven, Mass.—Early in the summer application was made to me by the Massachusetts Board of Harbor Commissioners for information which should aid them in the consideration of certain petitions from citizens of Martha's Vineyard and Nantucket, relative to the proposed opening of passage-ways through the beaches of Edgartown and Nantucket Harbors, and the closing of the inlet at the lagoon of Vineyard Haven. In response to this application, partial surveys were made by Assistants H. L. Whiting and Henry Mitchell, in order to furnish for the desired conclusions data drawn from the present condition of the places in question.

The coast section, in which these harbors lie, is of special interest because of the wasting of its headlands, the shifting of its beaches, and the singular tidal phenomena in the approaches by sound and sea.

As long ago as 1846, Lieutenant Commanding (now Rear-Admiral) Davis first called attention to the physical changes that were in progress along this part of the coast of Massachusetts, and in the same year Mr. Whiting made his first survey of the special locality in question. My own connection with these studies dates back to 1855, when the problems arising from Mr. Mitchell's tidal inquiries were referred to me for solution by my predecessor.

Aside, however, from these circumstances, which give to the neighborhood a scientific interest, the national importance of the two ports of Martha's Vineyard entitles them to watchfulness on the part of the Coast Survey, especially when fears for their utility and permanence are reflected in the petitions of intelligent citizens. In calling upon Mr. Whiting and Mr. Mitchell for reports concerning the changes, I instructed them to make such surveys, each in his own field, as might seem to them desirable.

It appears from these reports that the southern opening of Edgartown Harbor through Cotamy Beach has been closed upward of two years, and this closure has greatly embarrassed the fishing interests of the place, and given rise to apprehensions that the main entrance from the north may fill up because of the loss of tidal circulation. *No shoaling of the main entrance has, however, yet occurred.* In the channel-way over the bar the depth has increased one foot within the last twenty-five years, and is now sixteen feet at mean low water; but within Chappaquiddick

Point a shoaling has taken place opposite the town wharves. This shoaling extends quite across the channel, but has not seriously diminished the depth. That the apprehensions referred to are groundless I would by no means imply, but that the harbor, in its principal points of excellence, remains unchanged after two years of closure, at the south beach, is beyond question.

There have been several closures of the Cotamy Beach since the settlement of the island, and each new inlet has repeated essentially the history of its predecessor. It has first burst through the western portion of the beach, then worked to the eastward, till in course of time it reached the firm land at Wasque, where it made a stand, and finally succumbed after a somewhat protracted struggle for existence.

The levelings over the beach brought into sharp contrast the wind-worn and water-worn sections. The first gives for contours a congeries of curves; the second two systems of nearly straight lines. The beach where subject to the action of the wind is covered with irregular sand-hills, while that portion which is still under the occasional control of the sea presents two smooth surfaces declining in opposite directions from a crest-line. The sand-hills scarcely reach the dignity of dunes, but each water-worn section is in form and function a dike, differing, however, from the artificial structure as usually built in the order of its slopes.

These natural dikes appear to have the same form of cross section and nearly the same altitude of crest above the tide, whether observed upon the south shore of Martha's Vineyard or the east shore of Nantucket, as if the *direction* of exposure made no difference.

The survey of the interference tides of the sound and its approaches, made in 1854, becomes peculiarly valuable in connection with the schemes for opening the beaches I have referred to, since we are able to give rules showing at what age of the moon, and at what hour of the tidal day, the greatest difference of level between the lagoon and the sea may be expected.

Although the tides of this neighborhood are small, there is a great proportional difference between the morning and evening tides, between neaps and springs, and between consecutive springs. Moreover, the winds from different directions are unequal in their effects upon the absolute and relative elevations of the lagoon and the sea; so that the engineer cannot dispense with the tables deduced from the observations of Assistant Mitchell, and which are now on file in the Coast Survey Office.

After parts of the shore-line had been traced, hydrographic surveys were made in the course of the summer at Vineyard Haven and Edgartown Harbor; and, in addition, the tides and currents were carefully studied.

The charts were made by Sub-Assistant H. L. Marindin. Upon them are plotted in the aggregate 139 linear miles of sounding lines, and depths selected from 20,547 recorded casts of the lead, the positions of which were determined by 2,016 angles.

The tides were observed at three stations and the currents at ten. Particular attention was paid to movements along the bed of the sea, and the record shows about one thousand observations.

In the report of Assistant Mitchell special mention is made of the energy and skill shown by Mr. Marindin. The party was also assisted by students from the Rensselaer Institute of Troy, N. Y., and from the Institute of Technology of Boston, who volunteered in their vacations to take part in this instructive work.

Providence, R. I.—In order to provide for the insertion of the city of Providence in the usual generalized form on the chart of Narragansett Bay, a compilation from his own and other data was made by Assistant A. M. Harrison in August. Several years ago he surveyed the wharf-lines at Providence, and in so doing determined a few triangulation points in the vicinity. The data then gathered was applied to the existing city map for the compilation referred to, the object being to show in a general way the principal streets in their relation to the water-line. This work was done at an interval during which Mr. Harrison transferred his party for service that will be referred to under the next head.

Topography of Narragansett Bay, Rhode Island.—At the date of my report last year the detailed survey of Narragansett Bay was nearly complete. What then remained was mapped at intervals during the winter by Assistant Harrison, under whose charge the entire survey has advanced from the tracing of the shore-lines at the commencement of the work.

Sub-Assistant H. G. Ogden, after closing work last winter at the south end of Rhode Island, and before taking up duty in Section VII, joined Assistant Harrison at Wickford, on the west side of the bay, and assisted in adding some details to the survey in that vicinity. Mr. Harrison, in December, resumed the outstanding work in the neighborhood of Newport, and by the end of March completed the detailed survey. In the course of the winter he ran lines with the level, to an aggregate length of twenty-three miles. The harbor commissioners of Newport having previously assigned means for a minute survey of the wharf-lines, on a scale larger than that needed for the chart, Assistant Harrison was authorized, in April, to comply with their wishes. The requisite triangulation was made by Assistant Edward Goodfellow. From the twelve points thus given, Mr. Harrison traced and mapped the entire city front, and the shore-line for some distance above and below the city limits, on a scale sufficient for all legal requirements. This work was closed in May. Soon after, his party was organized for the summer, and, resuming the topographical survey at Narragansett Pier, extended it around Point Judith. For its progress to the westward, points were furnished by a party in charge of Assistant Sullivan. As in other parts of the survey of Narragansett Bay, the work along the north shore of Long Island Sound is intricate, the surface presenting topographical details of all kinds.

Mr. Bion Bradbury, jr., served as aid in this party during the season, and Mr. Stearns from the 10th until the end of August, when he was assigned to field duty in Lake Champlain. Both are now under instructions to accompany Assistant Harrison for service during the winter in Section VI. The plane-table survey going west of Point Judith was suspended early in November, when the following return was made in statistics:

Miles of shore-line surveyed	70
Miles of creeks and marsh-line surveyed	76
Miles of roads surveyed	72
Area of topography, (square miles)	20½

Tidal observations.—The self-registering tide-gauge established last year at North Haven, on the Fox Islands, as the principal tidal station and point of reference for that part of the coast of Maine, a general account of which was given in the report for 1870, has been kept running continuously. Its record is as nearly perfect as could have been anticipated. The apparatus for preventing the formation of ice around the moving parts of the tide-gauge has worked admirably, so that no tides have been lost from this cause. This station, judging from the curves traced by the gauge, appears to be well suited to the purpose for which it was selected. Mr. J. G. Spaulding, a very attentive observer, has been in charge, and has also kept up a regular series of meteorological observations.

Mr. Howland has continued the series of tidal and meteorological observations at the Boston navy-yard. The gauge there has failed to record tides during the coldest parts of winter, owing to frequent stoppages by ice. To supply the deficiencies in the record, parts have been added from the curve traced by the experimental glycerine-gauge working beside it. This last, however, has never yielded a perfect curve, but generally gives a close approximation. Short series of tidal observations have been made at several other places in this section by hydrographic parties as usual. These are primarily for the purpose of reducing soundings, but the registers lead to valuable results when studied in connection with those made at the permanent stations.

SECTION II.

ATLANTIC COAST, AND SEA-PORTS OF CONNECTICUT, NEW YORK, NEW JERSEY, PENNSYLVANIA, AND DELAWARE, INCLUDING BAYS AND RIVERS. (SKETCH No. 3.)

Triangulation from Point Judith westward.—In order to provide for the extension of the plane-table survey in this quarter, so as to complete a chart of the western approach to Narragansett Bay, thirteen points were determined by Assistant J. A. Sullivan in the latter part of July. Four stations were occupied with the theodolite, the last being in the vicinity of Charlestown, R. I., and about eight miles west of Point Judith.

Mr. W. H. Stearns aided in the triangulation, and made the field computations. The records of the work, with descriptions of the stations, have been filed with similar data pertaining to this

section. Assistant Sullivan communicated the results of his measurements to Assistant Harrison, and the plane-table survey, which was then in hand, went forward without delay. Under the head of Section VI mention will be made of the previous occupation of Mr. Sullivan. His aid, Mr. Stearns, was on service in that section, and later in the season reported to Assistant Cutts for duty on Lake Champlain, respecting which further remarks will be made before closing the notices of work in Section II.

Station marks.—From the earliest period of the survey marks have been set in the ground immediately under the position occupied by the theodolite at each point determined in the triangulation of the coast. Of themselves the marks are indestructible, and they are so placed as not to interfere with tillage, or, except where excavation may be needful, with any requirement in the advance of settlements. The stations have been selected generally with a view to their preservation. Nevertheless, some marks set for future reference may be disturbed by natural changes. From willful derangement, or removal, they are protected as far as possible by State laws, the importance being obvious of having at all times the means for fixing geographical positions beyond dispute.

Within the present year the examinations of Assistant John Farley at some of the principal stations on both shores of Long Island Sound confirm what was previously known in regard to the necessity of positive means for preserving the ground-marks. At Montauk Point the depression was found which indicated the place once occupied by the signal-pole, but the earthen cone buried at the foot of the pole had been dug out and destroyed. Mr. Farley took bearings and measurements sufficient for identifying the station. The marks on Shelter Island, being in a more sequestered place, had not been disturbed. Ordinary search for the exact point occupied at Friar's Head, on Long Island, was unavailing. The vicinity being now a deserted waste that was formerly well settled and cultivated, the reference marks could not readily be identified, but, in the absence of other than natural causes, the cone buried when horizontal angles were measured from that point may be regarded as in position. Farther westward on Long Island the small marble post set at Clarke station, in 1865, was readily found. This point is near Manhasset, and will be carefully preserved by the present proprietor, J. M. Clarke, esq. Three stations on the coast of Rhode Island were visited. Watch Hill station has not been disturbed, but Mr. Farley took additional ranges and views for identifying the point. The cone is probably in place on Champlin Hill, the outside reference marks being found as they were left. Such indications were wanting at Lantern Hill, but the cone was found in position.

Nickerson station, on the coast of Connecticut, is on an unfrequented hill. The signal-pole originally used was set between two large rocks, and these yet correspond to descriptions filed with records of the triangulation. At Williams's Hill, also in Connecticut, evidence gathered by Assistant Farley was satisfactory in regard to the security of the station. Sugar-Loaf Hill, farther westward, in the vicinity of New Haven, shows in the circlet of stones and a slight mound, the indications which were left by the triangulation party.

Evidence of the vicissitudes to which ground-marks are subject was revealed in the examination made by Mr. Farley of "*Yard*" station, near Philadelphia. Several years ago he was at the place, and recorded the position in which were found two pieces of the original earthen cone. The proprietor of the place, Mr. William Q. Baxter, with commendable interest, marked the position of the fragments by burying a granite bowlder, in which was previously fixed a leaden plate duly inscribed. Some time afterward, having occasion to move the ground in the vicinity, Mr. Baxter found the true cone. Assistant Farley visited the station in November, and, by additional measures and ranges related to the present surroundings, has recorded anew the exact position which was occupied by the theodolite while the triangulation was in progress near Philadelphia.

The results of his inspection were embodied by Mr. Farley in a special report, accompanied by sketches showing the vertical and horizontal contour of the ground at each station.

Triangulation and topography near New Haven, Conn.—The work of this year near New Haven was begun by determining points for the plane-table survey from two stations of the early triangulation. Mount Carmel was occupied to the northward of the city, and Milford station on the western side of the entrance to New Haven Harbor. For this service Assistant Edward Goodfellow took the field in June and closed in July. He occupied, in addition to the stations already

mentioned, three others in the immediate vicinity of the city. After turning in the records of his triangulation Mr. Goodfellow was assigned to duty, which will be further noticed under the head of Section VII.

As soon as possible after the preliminary triangulation was finished, Assistant R. M. Bache took up the topographical survey. This region comprises about a hundred square miles, and geologically consists of four ridges of trap and sand-stone, trending in a general north and south direction, bounded on the north by a transverse ridge of trap, the heights, as distinguished from the New Haven plain, varying from about two hundred to upward of seven hundred feet. It is drained through valleys, which are here a broad marsh, there a narrow seam, and again, a central rising plain diversified by rolling land. The vicinity is of singular topographical and geological interest. In his report Assistant Bache remarks: "All the various features conducive to beauty in map delineation are here present, and here, too, plainly legible, is a volume of the ancient physical history of the globe, in which, amid the work of the upheaving, depositing, and denuding forces through long ages, is seen the rude inscription of the great northern glacier, which molded these sand-stone hills, grooved and abraded the trap-rocks, and scooped out the valleys."

The map of a region containing one of the chief seats of learning in our country should include all the surface-features of special interest. When this work is done Professor James D. Dana, of Yale College, will represent upon copies of the plane-table sheets the results of his close study of formations, and thus meet all future inquiry by an example of the best method of geological delineation, applied to a minute topographical survey. Assistant Bache employed as aids in his party members of the scientific school of the college, who sought the incidental advantage of instruction in the use of the plane-table. In the recurrence of such instances the country at large, which, in its rapid development, is beginning to offer to skilled topographers a field of labor great in proportion to the number fitted to occupy it, will be benefited to the extent to which schools along the sea-board may avail themselves of proper opportunities.

Assistant Bache commenced the survey by running a number of lines of level, the two principal being up the central valley north of New Haven. This is a sloping plain nine miles long, which starts from the height of about thirty feet at the harbor, and attains an elevation of ninety feet at the base of Mount Carmel, the transverse ridge of trap before mentioned. He says: "Much curiosity being excited in regard to some of the chief heights, they were, by request, and with your special permission, published, dispelling long-cherished illusion on the subject. Mount Carmel, commonly reputed to be over nine hundred feet in height, is not much over seven hundred. East Rock, in the very outskirts of New Haven, once underwent a similar diminution of its grandeur; for, as we learn from one of a series of articles published in journal form in the Atlantic Monthly, entitled, 'A Virginian in New England thirty-five years ago,' East Rock was then reputed to be five hundred feet in height, but long since it has been known not to exceed three hundred and sixty. The popular tendency to exaggeration, growing out of the delight of wonder, is observable everywhere before the taking of accurate observation, no height or depth ever being underrated. The effect of special mental training in producing accuracy is perceptible even in guesswork."

The season was generally unfavorable for field-work, but, besides lines of level aggregating thirty-five miles, and plane-table triangulation giving points within an area of thirty square miles, Assistant Bache completed over six square miles of the most intricate of the topography. This area comprises the Quinnipiac River, and its branches and marsh, for two miles and a half from the mouth; the country eastward to the first main road, and the southern half of Quinnipiac Ridge, lying to the west of the river. The length of shore-line of rivers and other water courses surveyed was thirty-three miles, and of roads twenty-five miles. With the early spring, operations will be resumed by the party of Assistant Bache.

Survey of Lake Champlain.—The survey of Lake Champlain was resumed in July, and was continued until the close of the season in November. Two triangulation parties, two topographical, and one hydrographic party have been employed on the lake, some for the season and others for part only, according to the date of their return from the duties assigned on the southern coast. The triangulation now extends from Juniper Island northward to the boundary-line between the United States and Canada, and covers more than half and the most important part of the lake.

Two short bases for the verification of the work on the east and west arms were measured near the boundary. The triangulation was connected with and closed upon the astronomical station in New York, occupied in 1845 by Maj. J. D. Graham, United States commissioner for the determination of the boundary-line, and upon three of the iron monuments marking that line on the frontier of Vermont. The survey of the shore-line was continued as rapidly as the points required for its execution were furnished, and the number of parties specially detailed for this duty would permit, and embraces, with the exception of the northern part of the east arm, the entire field covered by the triangulation. The hydrography was carried on whenever the weather was at all favorable, the party in charge devoting the season to the broadest part of the lake, lying between Burlington, the Four Brothers, and Valcour Island, and to a close survey of such shoals and dangers to navigation as were found to exist. The several branches of work will be briefly mentioned in separate notices.

The early date of the appropriation by Congress, occurring at every alternate year or session enabled the parties at the south to continue in the field somewhat beyond the end of the fiscal year in sections where the weather was favorable, and it was not, therefore, until the middle of August that such of the returning assistants as were available could be assigned to the operations contemplated on the lake.

In the mean time, and with a view to hasten the progress of the work, Assistant R. D. Cutts, then engaged in the triangulation across New Jersey, detailed his aid, Mr. B. A. Colonna, to proceed to Burlington, Vt., and, with such assistance and means of transportation as could be found, to make a reconnaissance of the east arm; to lay out a scheme of triangulation with the usual quadrilaterals and checks, and to erect the necessary signals. Mr. Colonna reached Burlington on the 15th of August; was at work on the 19th, and before the close of September the signals, forty-two in number, were erected at intervals between Kibbe's Point and the boundary, including two or three on the Canadian shore, required for the determination of points on Missisquoi Bay, in Vermont. The energy and good judgment displayed in the execution of this duty received the commendation of the assistants whose future movements depended on his progress and success.

On the 28th of August Assistant Cutts finished the observations at Mount Holly, and started for Lake Champlain to take general charge of the checks and verification required at the closing of the work on the frontier. After visiting the different parties and making such arrangements as were deemed necessary, he proceeded to Alburgh Springs, near the boundary, expecting to find on the neighboring peninsula a site for a common base of verification for the two parallel series of triangles covering the east and west arms. Not succeeding in this, owing to the broken and rolling character of the country, he selected two sites, one on a level beach in the vicinity of Rouse's Point, and the other on the railroad bridge and track over the east arm, for the verification, respectively, of each series. At the same time a triangulation station, visible from both arms, was selected for the comparison of azimuth. The work of measuring the two bases was assigned to Sub-Assistant Perkins.

Triangulation of Lake Champlain.—In continuation of the survey of Lake Champlain, Assistant Charles Hosmer, after returning from work on the coast of South Carolina, took the field in July in the vicinity of Colchester Point. Signals were set up along the shores of the eastern channel of the lake as far north as Kibbe's Point, and intervening stations were occupied with the theodolite for the measurement of horizontal angles. Points having been thus determined, Mr. Hosmer resumed the shore-line survey with the plane-table. Separate mention will be made of the prosecution of that service. At Kibbe's Point the triangulation was taken up by Sub-Assistant F. W. Perkins, and was pushed northward as far as Ball's Island, to provide points in advance for the plane-table parties and for the soundings. Assistant G. A. Fairfield, after closing the season in Section IV, was instructed to co-operate in the determination of points on both shores of the eastern channel of the lake above Ball's Island. He commenced angular measurements on the 1st of September, signals for the purpose having been previously set up under the immediate direction of Assistant Cutts, by the Aid, Mr. B. A. Colonna, as already stated. Sub-Assistant Perkins having brought up the triangulation to Ball's Island, joined Assistant Fairfield, and, in going farther northward, stations on both sides of the channel were occupied at the same time. By this arrangement favorable intervals of weather, in a season which proved to be generally

unsuitable for such work, were improved to the utmost. The triangulation was extended northward through McQuam Bay, and beyond it through the eastern channel to the end of the lake, in Missisquoi Bay. Two stations of the triangulation done by this party are north of the United States boundary. Mr. Fairfield closed the triangulation of the eastern part of the lake on the 8th of October.

For verifying the triangulation which had been brought from the vicinity of Burlington, a base-line was measured by Sub-Assistant Perkins on the railroad bridge near Alburgh, Vt. This is about three miles south of the United States boundary. The measurement of the line, which is more than three-quarters of a mile, differs from the computed length by less than one inch and a third. In order to verify the triangulation, which at the same time was extended through the western channel of the lake above Plattsburgh, Mr. Perkins measured a base-line at Windmill Point, on the eastern side of that channel and opposite to Rouse's Point. The comparison between the computed and the measured length of the line is satisfactory. The triangulation of this season from Colchester Point northward into Missisquoi Bay, including the operations of Assistant Hosmer, Sub-Assistant Perkins, and Assistant Fairfield, is represented by the following statistics:

Stations occupied	49
Angles measured	313
Points determined	50
Number of observations	7,472

Assistant Fairfield is now engaged in triangulation work in Section IV, and Sub-Assistant Perkins in similar field-service in Section VII.

On the 10th of July Assistant S. C. McCorkle commenced the triangulation of the west arm of the lake, and the reconnaissance for a scheme of secondary triangles. Owing, however, to the urgent necessity of points for the plane-table party ordered to that locality, the latter duty was discontinued, and he devoted his entire time and attention to the progress of the tertiary work. The triangulation was taken up at the line Crab Island—North Sawyer's Point, and by the 22d of October it was connected with the base of verification and with a mark of the boundary-line near Rouse's Point. The preliminary computations show a satisfactory agreement between the length of the line as obtained by direct measurement, and its length as deduced from the Plattsburgh base.

In consequence of the ill-health of Mr. McCorkle, which he reported toward the close of July, Mr. William H. Stearns was detailed for duty, and on the 1st of September was assigned as aid. In his report Assistant McCorkle states that after the 5th of September Mr. Stearns erected six signals and made all the field observations up to the close of the season, and his zeal and attention to duty are commended.

The following statistics show the work executed by this party, in addition to which it may be mentioned that the computations were kept up with the observations in the field:

Signals erected	26
Stations occupied	33
Angles measured	202
Observations	5,250

Shore-line survey of Lake Champlain.—Two parties being available after midsummer for tracing the shores of Lake Champlain, the triangulation was urged so as to provide points for the completion of the field-work north of Burlington before the close of the season. This purpose has been accomplished.

Assistant Charles Hosmer resumed with the plane-table on the 1st of September at Colchester Point, and kept the field until the 25th of October. Five topographical sheets were projected, which he has returned to the office marked to represent the shore-line of the lake on the eastern side, from Colchester Point northward to Butler's Island. These comprise in the aggregate one hundred and one miles of the lake shore. In this survey Assistant Hosmer was aided by Mr. R. B. Palfrey.

At Shanty Point the work was taken up by Mr. J. N. McClintock, and extended northward to Stevenson's Point, the sheet of work comprising both shores of the eastern channel of the lake,

and at the northern extremity taking in the shore of McQuam Bay. Mr. McClintock traced twenty-four miles of shore-line, and at the end of October returned to field-service near Saco, Me.

Sub-Assistant H. G. Ogden took the field early in August to trace the shore-line of the western passages of the lake, with five sheets projected for the purpose. These he filled, and returned to the office at the end of October. Commencing at Cumberland Island light-house, Mr. Ogden defined the western shore of the lake, and the western sides of South Hero and North Hero Islands, and the entire shore-line of Isle la Motte, and from thence, northward to the United States boundary, both shores of Lake Champlain. Mr. Andrew Braid aided in this survey, and in November extended the topography of the eastern branch of the lake from the head of McQuam Bay northward, taking within the limits of two plane-table sheets the boundary of Vermont and the southern shores of Missisquoi Bay. The shore-line traced by the party of Sub-Assistant Ogden amounts to one hundred and fifty-two miles. These seven sheets represent also thirty miles of road.

Of the topographers employed in the survey of Lake Champlain, Assistant Hosmer had been previously engaged in Section V, and is now about to resume field-duty there. The previous work of Sub-Assistant Ogden will be mentioned under the head of Section VII, where his party is now ready to resume operations.

North of a line joining Ligonier Point on the western side with Shelburn Point on the eastern side, below Burlington, Vt., the shore-line and islands of Lake Champlain have been accurately traced and mapped. South of that line, the course being unbroken by islands, it is probable that the field-work may be advanced rapidly.

Hydrography of Lake Champlain.—In this work soundings have been extended from Bluff Point and the lower end of South Hero Island southward to Ligonier Point, in the vicinity of the Four Brothers, the space included coinciding in limits with the shore-line survey of last season. No means being available on the lake for hydrographic work, the small steamer Fathomer was transferred through the Erie and Oswego Canal into Lake Ontario, and thence by the Saint Lawrence and through the Saint John's Canal into the northern end of Lake Champlain. Sub-Assistant F. D. Granger joined the steamer at Plattsburgh on the 27th of July. Soundings were taken up in the course of a few days, and were prosecuted without interruption until the 1st of October. The party remained in readiness to improve every opportunity, but stormy weather continued for several weeks. Hydrographic operations were closed at the end of October. Many reefs were developed, some of which were unknown to the boatmen of the lake. While the soundings were in progress the level of water was carefully noted at Burlington and at Plattsburgh by simultaneous observations. The recorded depths were adjusted by reference to a bench-mark at Valcour Island.

Messrs. F. W. Ring and L. F. Chew served as aids in the hydrographic party, the former also in Section IX, where Sub-Assistant Granger was employed during the preceding winter and spring.

A synopsis is subjoined of the statistics of hydrographic work in Lake Champlain:

Miles run in sounding	615
Angles measured	3,915
Casts of the lead	14,131

The work is comprised on two hydrographic sheets. After turning them in at the office, Sub-Assistant Granger was assigned to duty in Section VIII.

Hudson River, New York.—In the course of the season Assistant Henry Mitchell conducted observations with reference to a physical survey of the Hudson. His study of the slopes of the river presents points of special interest. One of these developed in his preliminary report indicates that a line of inquiry has been opened promising direct results in regard to Hudson River. The criticism subjoined to the description of the method of determining elevations along the course of a tidal river is by a distinguished Belgian hydrographer, who has been many years engaged in a physical survey of the Scheldt, and who now proposes to take up the problem in the form to which it has been brought by the researches of the Coast Survey. Exclusive of many notes relative to temperature, density of water, and character of bottom, the record of work in the Hudson shows over seven thousand observations on the currents. Under the direction of Assistant Mitchell, the

details of the survey were prosecuted by Sub-Assistant H. L. Marindin, aided by a few students from the Rensselaer and Technological Institutes, who engaged in the service with enthusiasm during their vacation.

With the same party, aided also by Messrs. North and Wier, about thirteen soundings were made in the course of the season on the flats in New York Harbor, and in Buttermilk Channel. The plotting of this hydrographic work is now in hand, with a view to determine the cause of the changes that may be in progress.

Survey of Newark Bay, New Jersey.—The party of Assistant F. H. Gerdes was employed during the summer and autumn in shore-line surveys and hydrography in the vicinity of New York Harbor. Along the Passaic River the shore-line survey was revised and extended above Newark, and the survey of the banks of the Hackensack was continued to the point where it is crossed by the Erie Railroad. Portions of the Jersey Central, the Newark and New York, and the Boynton Branch Railroads coming within the limits of the survey were traced.

Assistant Gerdes, aided by Mr. C. P. Dillaway, sounded the rivers within the limits just mentioned, and also Newark Bay, revising, when needful, the sheets which represented the previous shore-line survey. On the bay and rivers this revision included an aggregate of about sixty miles. Tidal observations were commenced by the party of Mr. Gerdes in July and were continued until November. The schooner Dana was used in the soundings.

A synopsis of statistics is subjoined:

Miles of shore-line surveyed	28
Miles run in sounding	157
Casts of the lead	11,881

Assistant Gerdes is now engaged in inking the sheets resulting from the field-work of his party. In the preceding winter Mr. Dillaway had been employed in Section VIII, and is at present on hydrographic service in Section IV.

Triangulation near Barnegat, N. J.—In my last report it was stated that a reconnaissance had been made across New Jersey and a scheme found practicable for the connection of the primary triangulation on the Delaware with the coast series near Barnegat light-house. This scheme was commenced by Assistant R. D. Cutts toward the close of June. The level character of the country between Mount Holly and the coast rendered it advisable to erect high tripods and scaffolds for the elevation of the theodolite to secure the proposed length of triangle sides, and to save the expense in labor and damages that must otherwise have been incurred by cutting lines of sight through timber-land. Mr. B. A. Colonna, the aid in the party, put up suitable structures at Mount Holly, and at four other stations, being those immediately required for the proposed triangulation. The instruments were mounted at the Mount Holly station early in August, and the observations required there were completed before the end of that month.

While the observatories were under construction in July, Mr. Cutts accompanied me on a visit of inspection in Section I. During August and September he directed the preliminary field-work on Lake Champlain, as already mentioned elsewhere.

On the 4th of October Assistant Cutts returned to New Jersey and reorganized his party at Stony Hill, with the hope of completing angular measurements at that station before the close of the season. The underground marks of the old point occupied by Superintendent Hassler having been found by Mr. Colonna just previous to his departure for Lake Champlain, the tripod was moved from the eccentric to the true station, the distance to which was about eight meters. The theodolite was adjusted in its place, but in the middle of the month the smoke which generally hangs over the charcoal-burning district so thickened as to prevent observations. Soon after, Mr. Cutts being called away by other duties, the triangulation party was discharged for the season.

Altitude of stations.—The determination of the heights above mean tide of the primary stations has been continued, under the direction of Assistant Cutts, by a line of spirit-levels from Gloucester City, on the Delaware River, to Pine Hill station, and by others to Mount Holly. This duty was executed by Mr. Colonna during the month of June and the latter part of October, and according to the method described in my last report. The entire distance leveled, forward and back, was seventy-five miles. Bench-marks were established at the villages through which the lines passed, for the use of local or State authorities.

Assistant Cutts makes special mention of the energy and efficiency of his aid, Mr. Colonna, and commends also Mr. Louis F. Chew, who was temporarily attached to his party.

Topography of Great Bay and Little Egg Harbor, N. J.—The topography of Great Bay was taken up in the middle of May by a party in charge of Assistant C. M. Bache. After tracing the shore-lines, the surface features adjoining the water-line were carefully mapped. These include the small branches, and at the head of the bay several miles of the course of Mullica River. The entrance of the bay, known as little Egg Harbor, is comprised in this survey. The statistics of work are subjoined:

Miles of shore-line traced	337
Miles of roads	24
Area of topography, (square miles)	60

Sub-Assistant H. W. Bache assisted in this survey. The party is now engaged in Section IV.

Hydrography of Little Egg Harbor, Great Bay, and Absecom Inlet, N. J.—A party was organized to work in this section with the schooner *Bailey* during the summer and autumn under the charge of Sub-Assistant W. W. Harding. The bar of New Inlet, at Little Egg Harbor, was sounded, and also Great Bay. In August the progress made and circumstances attending the work gave hope for the completion of the survey allotted to the party. At this juncture Mr. Harding was taken with fever. He died on the 25th of September. The care of the schooner Bailey devolved on the aid, Mr. J. J. Evans, until the arrival of Sub-Assistant W. I. Vinal, who was then in service on the coast of Maine. Mr. Vinal reached Atlantic City on the 14th of October. Signals were set up and tidal observations commenced without delay. At favorable intervals until the 1st of November soundings were made outside and through Absecom Inlet, and inside of the inlet so as to develop all the water-passages within three miles of the coast-line. A bench-mark was established at Atlantic City and others at New Inlet and Great Bay, where the tides had been observed during the summer by Mr. Harding. For the determination of positions twelve stations were occupied with the theodolite on shore while the soundings were in progress. The statistics of the hydrographic work are as follows:

Miles run in sounding	313
Angles measured	825
Number of soundings	17,320

After the return of the schooner Bailey to Baltimore for repairs Mr. Vinal completed and turned in the records of the work on the coast of New Jersey, and is now making preparations for hydrographic service in Section V.

Survey of the "Horse-Shoe," (Delaware River,) and of the Schuylkill near Philadelphia.—This work was undertaken at the request of the delegation in Congress from the city of Philadelphia, the object being to determine the practicability of expedients for keeping the channel of the Delaware from being gorged with ice in the vicinity of the Horse-Shoe. In order that the question might be met with reference to the probable limits within which the observed effects were wrought, a close survey of the banks of the Delaware was made from the vicinity of the navy-yard to the lower end of League Island. Subsequently, at the instance of the delegation, the survey was made to include the lower part of the Schuylkill.

In December, 1870, Mr. A. Lindenkohl traced the shore-line of the Delaware from the navy-yard to a point opposite to the middle of League Island, and the opposite or New Jersey side from Kaighn's Point to Red Bank. The dikes remain as shown by the old survey, but Mr. Lindenkohl found that the river at two places has been very much narrowed by artificial structures. Below the navy-yard these extend into the river from both sides, so that the breadth across to Kaighn's Point is five hundred metres less than it was twenty-five years ago. At Gloucester, about two miles down the river, large factories stand where the old river-flats were, and two hundred metres outside of the former shore-line. The ferry-wharf at Gloucester is about a hundred metres beyond the old shore. On the opposite side "Broad Marsh" seems to be washing away between Greenwich Point and League Island, the last survey showing the loss of a strip about seventy metres in width.

By reason of the severity of the season and prevalence of ice in the river it was found im-

practicable to make the soundings during winter. Assistant Charles Junken, however, observed while ice was forming on the shoals at and near the Horse-Shoe, and also the conditions under which the ice gave way and its course in drifting after a thaw or freshet. Such suggestions as seemed to bear upon the question of lessening the tendency of the ice to drift into Ladd's Cove were embodied in notes and placed on file in the hydrographic division.

In August, of the present year, the desired soundings were made by Assistant F. F. Nes. Two sheets were projected to represent the results on a scale sufficiently large for any ulterior purpose. In the Delaware numerous and careful soundings were taken between Point Airy, at the lower end of Windmill Island, and the light-house abreast of Fort Mifflin. The Horse-Shoe Shoal was specially developed, and also the Back Channel as far as the bridge, between League Island and Philadelphia.

Subsequently, Assistant Nes sounded out the Schuylkill from its mouth, near League Island, upward to Fairmount, completing the survey on the 2d of December.

The statistics are subjoined:

Miles run in sounding	255
Angles measured	6,412
Number of soundings	21,295

Two tide-gauges were kept in operation by the hydrographic party, one at the Philadelphia navy-yard and the other at League Island.

Mr. T. J. Lowry aided in this work and in similar duty in Section VIII. The previous service of the party of Assistant Nes will be mentioned under the head of Section IV.

Tidal observations.—Mr. R. T. Bassett, an experienced tidal observer, has continued the series of tidal observations at Governor's Island, in New York Harbor, with a self-registering gauge, occasionally noting the reading of a box-gauge at the Hamilton-avenue ferry in Brooklyn for comparison with the other. This series, though at times somewhat broken, has furnished data for many purposes. Indeed, no improvement can be made along the shores of the harbor or of its connected waters, nor can any costly structure be properly erected near the water-line without resort to the tide-levels which may be deduced from this series of observations.

SECTION III.

ATLANTIC COAST, AND BAYS OF MARYLAND AND VIRGINIA, INCLUDING SEA-PORTS AND RIVERS

(SKETCH No. 4.)

Topography and hydrography of the Broadwater, Va.—The name *Broadwater* which has been given to a marshy expanse of the coast of Virginia, north of Cape Charles, is somewhat applicable at high tide. At other times only the numerous channels are seen that meander through the marsh. The lower part of the Broadwater was surveyed and sounded last year. In December, 1870, Assistant J. W. Donn resumed the work, and by the end of the season developed the coast region extending to the northward as far as Metompkin Inlet. Sub-Assistant L. B. Wright was attached to his party. The schooner Bailey was used for transportation. With the plane-table Mr. Donn mapped the details of the mainland, prosecuting the survey there when the weather was unfavorable for sounding in the channels of the Broadwater. As before stated, much of the area to be passed over was a grassy marsh at low tide; hence ordinary methods for topographical delineation were of no avail. Some of the channels which traverse these extensive flats are of local importance. The Great Machipongo flows for fifteen miles through a marsh so wide that the river course is visible only at low water. In making his survey Assistant Donn determined first, and mapped the high-water lines along the mainland, and with them the hummocks, islands, and inlets as they appeared at that stage of the water. Next, the line of grassy marsh was traced, with the intersecting channels. Lastly, the creeks and channels were surveyed, to show their true courses, and the depth at low tide. In the hydrographic survey, lines of soundings were run with a view to develop the channels alone, the depth elsewhere being often insufficient to float the sounding-boat.

This work, prosecuted with great patience and energy by Assistant Donn and Sub-Assistant Wright, completes the survey of the outer coast of Virginia between the head of Magothy Bay and Metompkin Inlet.

A synopsis of statistics is appended:

Miles of shore-line traced	475
Miles of roads	112
Area, (square miles)	188
Miles run in sounding	302
Angles measured	4,094
Number of soundings	22,019

After turning in the sheets of this work, the party of Assistant Donn went on field-service in Section I. He is now making preparation to extend the survey of the James River, Va. Sub-Assistant Wright will conduct a party during the coming winter in Section IX.

Latitude, azimuth, and magnetic observations at stations on Chesapeake Bay.—The operations of the party of Assistant A. T. Mosman in this and in other southern sections, extending through twelve consecutive months, will be mentioned in the usual geographical order, and not in the order in which his nine distant sites of work were successively occupied. During the inclement months of the season, which would not have permitted field-work in this section, the party was engaged on the Gulf coast, and afterward in Section IV, as will be stated hereafter.

Mr. Mosman and his aid, Mr. Edwin Smith, jr., landed on the 19th of July at Cove Point, Maryland, and as soon as possible mounted the astronomical instruments in a temporary observatory at *Calvert station*, one of the points in the primary triangulation which passes southward through Chesapeake Bay. At favorable intervals preceding the 20th of August ten nights were employed in observing twenty-four pairs of stars for latitude, one hundred and thirty-nine measurements being recorded. Two sets of observations were made for the micrometer value. Time was determined in the course of thirteen nights by forty-nine observations on eighteen stars; and for azimuth of the line to Meekin's Neck, two hundred and sixteen observations were recorded on five nights in August and September with theodolite No. 16.

At Calvert station the magnetic declination was derived from observations continued through three days; five sets of experiments were made for vibration, and eight sets for deflection on two days. The dip of the magnetic needle was ascertained in the usual way.

The observations for azimuth were closed on the 6th of September. Mr. Mosman soon afterward turned in at the office an aggregate of twenty-three volumes, with duplicates of the same, comprising the records of the stations previously occupied, and all the computations due from his party. He passed the remainder of the season in fixing the latitude and longitude of points in Ohio and Kentucky, mention of which will be made under the head of Section VII.

At Tangier Island, in Chesapeake Bay, Virginia, observations were commenced by Assistant Mosman on the 16th of June, and were closed by the middle of July. Latitude observations were made during nine nights on twenty-three pairs of stars by one hundred and forty-four observations with meridian telescope No. 7. The micrometer value was acertained as usual. Time was determined by eighty measurements with twenty-nine stars on twelve nights, and three other nights were employed in observations for azimuth of the line to Watts' Island light-house. This is not one of the principal stations in the triangulation of Chesapeake Bay, and the geodetic station at Smith's Point light house could not be seen from the ground at the azimuth station. To avoid loss of time and the expense incident to building a platform which must needs be forty feet high to bring into view Smith's Point, Mr. Mosman occupied as an eccentric station a chimney of the old Beach House on Tangier Island. At this point were recorded by the aid seven hundred measurements of the horizontal angles made by lines joining the chimney with the two light-houses and the azimuth station. The azimuth was observed at the eccentric station on six nights by six hundred and twelve measurements with the theodolite.

Magnetic declination at Tangier Island was determined on three days, and the dip and horizontal intensity were ascertained in the usual manner.

Wolf-Trap, Va., a primary station on the west side of Chesapeake Bay, below the mouth of the Rappahannock, was occupied by Assistant Mosman from the middle of April until the 7th of June. A signal was erected at New Point Comfort, primary station, and the angle between it and the light-house at New Point Comfort was determined from Wolf-Trap by one hundred and forty

four measurements with the theodolite signals were also set up for determining the position of Wolf-Trap-Spit light and York-Spit light, one hundred and ninety-two measurements being recorded for that purpose. Both light-houses were occupied with the theodolite as stations.

For the latitude of Wolf-Trap station Mr. Mosman and his aid, Mr. Smith, observed and recorded, during sixteen nights, an aggregate of two hundred and ninety results from forty-five pairs of stars. Sixteen stars were observed on ten nights, for time and instrumental corrections, by fifty-four measurements. The value of the divisions on the level and of the micrometer were carefully ascertained. For azimuth two hundred and seventy-six measures were made, on six nights, of the angle between Polaris and New Point Comfort light, which, not being coincident with the primary station, is referred to it by the angular measurements already mentioned.

At Wolf-Trap a complete set of observations was made by Assistant Mosman for the magnetic declination, dip, and horizontal intensity; and a full set by his aid, Mr. Smith, who also took part in the observations for latitude, azimuth, and triangulation.

Further mention will be made of the operation of this party under Section IV.

Magnetic observations.—At the station near his own dwelling, on Capitol Hill, Washington City, the usual annual series of observations were made in June by Assistant Charles A. Schott, chief of the computing division. From these were determined the magnetic declination, dip, and horizontal intensity. The results serve as a check upon conclusions heretofore drawn in regard to the secular variation of the magnetic elements.

Pendulum observations.—Among the instruments deemed useful in the outfit of the expedition now in the arctic regions, under Captain Hall, was included the pendulum belonging to Dr. I. I. Hayes, and which had been used by Mr. Sonntag in a previous expedition to Smith's Sound. Careful experiments were made with that bar some years ago by Prof. George P. Bond, at Cambridge Observatory, Massachusetts. Assistant Schott made a new series of observations with the pendulum in the early part of summer, and recorded the results. The instrument was then packed at the office, and delivered to Captain Hall, with full information in regard to the experiments needful for purposes of comparison.

Hydrography of the Chesapeake estuaries.—The descriptions in my report of last year included mention of the work done by the party of Sub-Assistant W. W. Harding previous to December 1870. Soundings and tidal observations were completed on the branches of Chester River on the 10th of that month, and similar work was commenced a few days after in the upper waters of the Severn River, and in the branches adjoining Annapolis Harbor, where soundings were prosecuted until the channels were closed by ice. This occurred near the end of the year. The party in the schooner *Hassler* returned by the 1st of March, and completed the hydrography of the vicinity of Annapolis. Before the close of that month a number of small branches of the bay along the eastern shore were sounded out, Sub-Assistant Harding, as in other cases, tracing the shore-line. In the course of ten days, preceding the 5th of April, the several branches of the Big Choptank were traced and sounded, and, subsequently, the arms and creeks that make into the Little Choptank, also on the eastern shore of Chesapeake Bay. Twenty-six of the smaller branches of Chesapeake Bay were traced and sounded out by the party during the winter and spring in addition to the work done in the head-waters of the Severn above Annapolis, and in the body of the bay between Thomas' Point and Tally's Point.

During much of the time the party was of necessity under way in the vessel, the sites of work not being continuous, but, as before explained, limited to the small branches and estuaries which were passed by in the first issue of the chart of Chesapeake Bay for the general purposes of commerce.

In the aggregate, thirty-nine miles of shore-line were traced by Mr. Harding; the lines of soundings were in all about one hundred miles, and are represented in the record-books by depths found with fifty-seven hundred casts of the lead.

Late in April Sub-Assistant Harding was assigned to service in Section IV, and but for severe lameness, which disabled him temporarily, he would have conducted a party for the survey of the channels of Cape Fear River. On his recovery he organized a party for hydrographic duty in the schooner *Bailey*, in Section II, and had well advanced the work under his charge when he was seized with illness, which caused his death, as mentioned in the obituary notices in the introduction to this report.

Triangulation of the James River, Va.—This work has been carried on by Assistant R. E. Halter, with but slight interruption, from its commencement in October, 1869, until May last, when it closed at stations near City Point. At the date of my last report the triangulation had advanced as far as the line, *Cypress Shields*, and from this base it was continued up the river until the close of December, 1870, when the running ice compelled Mr. Halter, for the safety of the schooner Bowditch, to seek an anchorage in Elizabeth River. On the 6th of January he returned to the field, and although still, at times, delayed by ice and bad weather, was enabled to continue the triangulation with advantage throughout the winter and spring.

On the 5th of April his work and scheme of triangles were inspected by Assistant R. D. Cutts, in charge of the secondary triangulation. An examination was at the same time made in regard to the practicability of enlarging the scheme with a view of connecting with the primary triangulation coming down, parallel with the coast, through the eastern valley of Virginia. For this verification, however, on the scale desired, the character of the country offers few natural facilities. It was, therefore, deemed advisable to suspend the triangulation for the present at City Point. The party was disbanded early in May. Assistant Halter, after finishing his computations, was assigned to duty in Section VIII. The statistics of the season on James River are subjoined:

Signals erected	32
Stations occupied	21
Number of observations	8,546

Assistant Halter was aided in this section by Mr. B. A. Colonna.

Primary triangulation in Virginia.—For continuing the main triangulation southward along the Blue Ridge, Assistant C. O. Boutelle made a reconnaissance early in the summer, and selected stations for extending the work to the vicinity of Lynchburgh. Of these he subsequently occupied two, and completed at them the usual series of geodetic observations, closing operations at the first, (Clark's Mountain,) near Rapidan, on the 8th of September. At this station astronomical and magnetic observations were recorded, those for latitude and for time from measurements by Sub-Assistant F. Blake, and for the magnetic elements from observations by Messrs. A. H. Scott and C. B. Boutelle, aids in the geodetic party.

The sides of the primary triangles, in this part of the series, range from twenty-three to sixty-four miles in length. From Clark's Mountain the signals at nine stations were observed on, including one near Fredericksburg taken in for connecting with the main work the secondary triangulation, which passes up the Rappahannock River. At Bull Run Mountain, subsequently occupied, the junction of the river survey with the primary work was completed. Assistant Boutelle made the measurements for horizontal and vertical angles, and determined the azimuth, using an artificial horizon of mercury without any glass roof, and observing within two hours of the elongation of the pole-star. Special care was bestowed on the determinations for azimuth.

Gulf Stream.—While crossing the Gulf Stream, on the 8th of December instant, in the steamer *Hassler*, Assistant L. F. Pourtales recorded the temperature of the water at the surface. A transcript of the observations forwarded on the arrival of the steamer at St. Thomas shows that the warm water, which is characteristic of the Gulf Stream, was, early in this month, more than half a degree farther south than it was in the year 1860, and that the band of warm water was somewhat broader. A colder band was crossed in going farther southward, but no other alternations of cold and warm water. The observations were made in the latitude of Cape Henry.

Tidal observations.—At Old Point Comfort the series of observations with a self-registering gauge has been continued by Mr. W. J. Bodell. The record includes curves for many years, but the series has been often interrupted by storms, the situation being of necessity exposed to the force of the sea. The instruments are now in good condition, and the fixtures at the station have been strengthened. A new box-gauge and a porcelain staff were recently set up for comparisons. Valuable results are expected from the discussion of this series of tidal observations. Several short series of tides have been recorded in the course of the season by the hydrographic party engaged in the waters connected with the Chesapeake, and these have materially added to our knowledge of the tides in this section.

SECTION IV.

ATLANTIC COAST AND SOUNDS OF NORTH CAROLINA, INCLUDING SEA-PORTS AND RIVERS.

(SKETCH No. 6.)

Triangulation of Pamplico Sound, N. C.—The work of this year, by Assistant G. A. Fairfield, includes also the triangulation of Pungo River, the third in order of the large branches of Pamplico Sound.

The steamer *Hitchcock*, one of the new vessels, was expected to be in readiness for service about the middle of January, but some changes needed in the machinery delayed the delivery of the vessel. Mr. Fairfield joined the steamer, at Norfolk on the 27th of February, and reached New Berne on the 6th of March. A few days after, the party, having taken in Assistant Mosman and his aid, as stated elsewhere, landed at Portsmouth. There Mr. Fairfield set up a tripod and observing scaffold, and, while Mr. Mosman was engaged in astronomical work, the requisite angular measurements were made for connecting the base-line with the triangulation of Pamplico Sound. A granite post was set by the triangulation party to mark the northeast end of the base-line, which is coincident with the station occupied by Assistant Mosman.

Early in April the triangulation of Pungo River was taken up, and by the end of May that work was completed, making full provision for the plane-table survey in the course of the coming winter. Points were determined on the shores to a distance of twelve miles above the mouth of the river. Returning to Ocracoke Inlet Assistant Fairfield occupied, in succession, as primary stations the three light-houses in that vicinity, and also the southwest end of the Portsmouth base-line, and was engaged with the theodolite in this part of the triangulation until the end of July. The general statistics of the field-work are as follows:

Signals erected	14
Stations occupied	18
Angles measured	107
Number of observations	5,484

Sub-Assistant F. W. Perkins rendered effective service in this party, and was also associated with Assistant Fairfield in duty which was prosecuted during the summer, as has been stated under Section II. The triangulation of Pungo River is already connected with that of Pamplico Sound. Angular measurements are yet to be made at Swan Quarter Island, after which the lines in the scheme of triangles increase to an average length of about twenty miles. The work is about to be resumed by Assistant Fairfield.

Latitude, azimuth, and magnetic observations at Portsmouth, N. C.—Assistant A. T. Mosman reached New Berne late in February after completing field duty, which will be mentioned under the head of Section VII. The triangulation party, in charge of Assistant Fairfield, arrived in Pamplico Sound a few days after, in the steamer *Hitchcock*, and, before taking up routine work, landed the astronomical party and instruments at Portsmouth, on the south side of Ocracoke Inlet, and assisted in setting up the temporary observatory needed at the northeast end of the base-line, which had been measured by Assistant Fairfield near Portsmouth. The astronomical instruments were in place by the 16th of March, but unfavorable weather permitted only occasional observations until the 27th of that month. Clear nights following until the 5th of April, Mr. Mosman and his aid, Mr. Edwin Smith, jr., completed the needful observations. Twenty-four pairs of stars were observed on for latitude, and in the course of ten nights one hundred and thirty-seven results were recorded. For value of the micrometer in the meridian telescope No. 7, five sets were observed on four nights; and as many sets on two days for the value of the level divisions. Time and instrumental corrections were ascertained from forty-nine observations on eighteen stars, tests for the purpose being made on thirteen nights. The azimuth of the line to Ocracoke light-house was determined from one hundred and forty-four measurements on five nights. The magnetic declination, dip, and horizontal intensity were ascertained from observations continued through four days at the station near Portsmouth.

Assistant Fairfield received the astronomical party on board of his vessel on the 7th of April, and next day returned to New Berne. From thence the instruments to be used by Mr. Mosman, in

Section III, were sent by rail to Norfolk. His operations in that section have been already described.

The computed results and records pertaining to the observations made by Assistant Mosman in this section have been received, and placed in the office. Under the head of Section VII mention will be made of the previous occupation of the astronomical party.

Topography of Pamplico River, N. C.—The survey made by Assistant F. W. Dorr in this section comprises the topography of the shores of Pamplico River above Lee's Creek, and extending to the immediate vicinity of Washington, N. C. With the addition of some few details to represent the town outlines the survey of the river will be complete. All the important creeks or branches of the Pamplico are represented on the plane-table sheets, and, in order to include them, the survey necessarily was carried back more than the usual distance from the shore-line of the river. Its branches mapped this year are Durham's Creek, Bath Creek, Blount's Creek, with the expanse known as Blount's Bay, Chockowinity Bay, Broad Creek, and many of less note. The roads traversing both sides of Pamplico River were traced, and in other particulars the survey of this year was made conformable to that of the lower part of the river.

This work was taken up on the 6th of December, 1870, Mr. Dorr using, as heretofore, the hull of the steamer Hetzel for quarters, and as means for moving from place to place in going up the river. The season was marked by unusual cold, and in consequence the vessel was blocked in ice for several days. Party operations were much impeded from this cause during three weeks.

A little village called Bath, marked on the lower of the two plane-table sheets of this season, is of interest by reason of its historical associations, that being, in the colonial period, the official residence of the chief magistrate. At present the channel which leads up to the village has only seven feet of water at the ordinary stage.

Durham's Creek affords eight feet of water through a narrow, winding channel as far as the steam saw-mill, just inside of the entrance. Another mill about a mile farther up the creek meets large orders from northern factories for spindles and spools, which are made of dogwood, persimmon, and other suitable wood found in the vicinity.

The shores of Pamplico River alternate between sand and a narrow fringe of marsh, with occasional bluffs and some high land. On the south shore near Nevill's Creek (Sketch No. 32) the bank is forty feet high.

At Hill's Point, six miles below the town of Washington, the river is only one mile wide, and there, during the war, two rows of piles were set quite across the channel to obstruct the upward passage of the United States gun-boats. Many of the piles remain in place and the passage through is at present quite narrow.

Assistant C. T. Iardella ably co-operated in the survey of Pamplico River. Mr. A. P. Barnard served as aid in the plane-table party. The statistics of work are as follows:

Miles of shore-line, river, and branches	163
Miles of streams	431
Miles of roads	415
Area, (square miles)	194

The very large area developed with a single plane-table gives evidence of close and conscientious application to duty by the members of the party. In the course of the present winter Assistant Dorr will map the vicinity of Washington, N. C., and then continue plane-table work along the western shore of Pamplico Sound, and include the survey of Pungo River. In conjunction with Assistant Iardella he prosecuted field-work during the summer, as stated under the head of Section I.

On the 24th of May the steamer Hetzel was laid up at Washington to be in readiness for the completion of the survey at the head of Pamplico River.

Hydrography of Pamplico River, N. C.—In its progress from the southward the hydrography of Pamplico Sound rested, at the opening of the present season, at the entrance of Pamplico River. Soundings in the lower part developed the channels of that river as far upward as Indian Island. Assistant F. F. Nes made preparations in December, 1870, for completing the hydrography of Pamplico River, with a party in the schooner Arago, Assistant Dorr having previously advanced

the plane-table survey from the entrance as far up as Lee's Creek. The vessel, needing extensive repairs, was placed in charge of the senior aid, Mr. W. I. Vinal, at New Berne. Other preparations being made in the same interval, the party took up soundings in Pamplico River on the 23d of February. Assistant Nes had been entirely disabled by rheumatism, which seized him at the approach of winter, while closing hydrographic work on the coast of Maine. He was in consequence unable to join his party in Section IV. Under his general direction, however, the operations were carried forward with success by Mr. Vinal. The work is comprised on three sheets, taking in all the shore-line which has been traced by the plane-table party. Mr. Vinal recorded tidal observations at four stations in Pamplico River. In going up the channel sextant angles were measured at forty-five stations. Fourteen buoys were determined in position by occupying forty-three points along the banks of the river. For the adjustment of soundings the party in the Arago set up sixty-one signals. Mr. Vinal was aided by Mr. R. B. Palfrey until the 17th of March, and until the close of work, near the end of May, by Mr. J. J. Evans. The sailing-master of the Arago, Capt. Thomas H. Ferney, besides his care of the vessel, rendered important service in this hydrographic survey. The general statistics are:

Miles run in sounding	665
Angles	1,927
Number of soundings	49,704

The depths, tides, and angles are registered in twenty-four volumes.

At the approach of spring Assistant Nes was able to resume duty afloat. His occupation during the summer and autumn has been mentioned under the head of Section II. Mr. Vinal was at the same time on duty in a party in Section I, but was sent to the coast of New Jersey in October to continue hydrographic work which had been suspended by the death of Sub-Assistant Harding. A like distress occasioned the transfer of the aid, Mr. Palfrey, to Section VII, as will be noticed under that head.

Hydrography of Hatteras Shoals, N. C.—Under the expectation of favorable weather in July, Acting Master Robert Platt, United States Navy, Assistant Coast Survey, sailed early in that month from Norfolk with his party in the steamer Bibb, and set signals along the beach of Pamplico Sound, the intention being to run lines of soundings to seaward and develop the depth now to be found in crossing the Hatteras Shoals. Several lines were successfully run before the end of July. Bad weather then set in. Ten times during the month of August the steamer was on the shoals, but no weather suitable for completing the survey at that season presented itself. The work was subsequently accomplished and the results will be marked on the general sailing chart of this section.

The hydrographic party in the steamer Bibb was previously engaged in Section VI.

Topography of Bogue Inlet, N. C.—East and west of Bogue Inlet, at the opening of the winter season, an interval was outstanding in the topography of the coast of North Carolina. Assistant Hull Adams reached Swansboro on the 19th of December, 1870, and organized a party for plane-table service, the intention being to make the belt of topography in that vicinity conformable to the survey of the shores of Bogue Sound, where the coast topography was suspended in 1868. When the party arrived the cold was severe and the sound was soon after frozen over. The sand-hills, moreover, had so changed that none of the points marked in the triangulation which was made previous to the war could be identified. Assistant Adams, in consequence, started from stations marked on the shores of Bogue Sound in 1868, and going westward renewed the triangulation by means of the plane-table, tracing at the same time the outside shore-line as far in that direction as New River Inlet. This is about twenty-five miles from the point at which he started. His work completes the survey of Bogue Sound, including also the inlet of that name, and the mouth of White Oak River in the immediate vicinity of Swansboro. Farther westward the outside shore-line was traced, including the openings known as Bear's Inlet and Brown's Inlet. The details inside of the shore-line will be mapped in the course of the present winter. Before leaving the section, at the end of May, Mr. Adams and Sub-Assistant Eugene Ellicott, who was attached to his party, found the marks of eight of the stations occupied some years ago in making the triangulation between Swansborough and New River Inlet. These will aid much in the early comple-

tion of the detailed survey on this part of the coast of North Carolina. Bogue Sound, toward its western end, terminates in marsh at a point about four miles from Swansboro, and the marsh continues westward as far as New River Inlet. There are, however, two channels extending through the marsh to Swansboro. Bogue Sound is there about four miles wide, but less to the eastward where the water deepens. The detailed survey was suspended at a point about three miles west of Swansboro, where it is now about to be taken up for early completion by Assistant C. M. Bache.

The statistics of the work, as far as yet accomplished, are as follows:

Miles of shore-line surveyed	198
Miles of inner marsh-line	28
Miles of shoals	20
Miles of roads	27
Area, (square miles)	73

Sub-Assistant Ellicott continued in service with this party until the 13th of May, when he was assigned to duty of which mention will be made under the head of Section XI.

Assistant Adams passed the working season at the North in Section I, as already mentioned.

SECTION V.

ATLANTIC COAST AND SEA-WATER CHANNELS OF SOUTH CAROLINA AND GEORGIA, INCLUDING SOUNDS, HARBORS, AND RIVERS.

Topography and hydrography of the sea-island channels of South Carolina.—The survey in this section has been advanced to include two of the branches of Coosaw River, near the head of Saint Helena Sound, and also the upper waters of Port Royal Sound, and of Calibogue Sound.

Having refitted his vessel, the schooner G. M. Bache, at Savannah, Assistant Charles Hosmer resumed work on the sea-islands on the 12th of December, 1870, aided by Mr. J. N. McClintock. Joining with plane-table details which were mapped in the spring of 1870, on the north shore of Savannah River, the survey was continued northward and eastward, and included in its course the upper part of Wright's River, and all the water-passages between it and Broad River. The passages were sounded, and some additional triangulation needed for plane-table work near the Savannah, and also for the extension of the survey so as to take in Chechessee River, was made by the party. Twelve stations were occupied with the theodolite for this purpose. The detailed survey is comprised on two sheets.

Later in the season the party developed by a shore-line survey and soundings a stretch of six miles in Bull River, and in the same region about four miles of the course of the Combahee River. The parts surveyed include the phosphate deposits, so valuable for the fertilizing properties of the material which is largely taken from the beds of the rivers.

At the end of April the schooner Bache was laid up at Savannah. The following is a synopsis of the field-work by this party:

Miles of shore-line of rivers surveyed	155
Miles of creeks and marsh surveyed	192
Miles of roads surveyed	40
Area of topography, (square miles)	78
Miles run in sounding	326
Angles measured	1,031
Casts of the lead	32,309

The field-work subsequently done by Assistant Hosmer has been described under Section II, where Mr. McClintock was also employed after several months of service in Section I.

In the course of the winter, while engaged in bringing up computations resulting from his field-work in this section, Assistant C. O. Boutelle at intervals examined the navigable rivers in the vicinity of the sea-islands of South Carolina, and noted such peculiarities as must be of account in deciding upon the method proper for the survey of these channels of communication

with the upland district. His observations were communicated in the form of a comprehensive report. The facts embodied are of much value, and bear directly on the future development of this interesting region of the southern coast. Mr. C. B. Boutelle served as aid in this section, and subsequently with the party in Section III.

SECTION VI.

ATLANTIC AND GULF COAST OF THE FLORIDA PENINSULA, INCLUDING THE REEFS AND KEYS, AND THE SEA-PORTS AND RIVERS. (SKETCH No. 7.)

Topography of Nassau Sound, Fla.—The work to be noticed under this head completes the survey of the inland water-passages between Saint Mary's River, at the boundary of Georgia, and Saint John's River, Florida. The passages, as mentioned in previous reports, permit a water communication along a route generally parallel with the outer coast-line of the Southern States, but free from the risk of sea navigation.

Assistant W. H. Dennis commenced operations this year on the 3d of January. After tracing the shore-line of Amelia Island he determined the positions of signals for the use of the hydrographic party of Assistant Webber, and then proceeded with the plane-table survey of Nassau Sound. The sheet returned shows the outlines of that body of water and its tributaries, the principal ones being South Amelia River and Nassau River. Of these streams the former makes part of the inland water communication before mentioned.

The work done by Mr. Dennis represents the ground surface from the coast-line to a distance of seven miles westward. It comprises Nassau Sound, with the lower part of Amelia Island on the north side, and Talbot Island on the south side of the entrance. The surface features are like those of the southern coast generally, there being a great deal of marsh traversed in all directions by rivers or creeks. On the main, pine barrens are common, but the sandy coast islands bear, besides pine, also a growth of oak, with much underbrush.

Mr. Bion Bradbury, jr., served as aid in the plane-table party. Field-work was closed on the 23d of May. After laying up the schooner Caswell at Jacksonville, Assistant Dennis returned to the north, and during the summer was engaged in Section I. On the coast of Florida his work was furthered by occasional aid from the hydrographic party of Assistant Webber. The statistics of the plane-table survey of Nassau Sound are as follows:

Miles of shore-line traced	137
Miles of roads surveyed	52
Miles of marsh-line surveyed	103
Miles of creeks surveyed	83
Area of topography, (square miles)	104

Excepting some few water-passages between the sea-islands of South Carolina, the plane-table survey is now complete from Charleston southward to Saint Augustine, on the coast of Florida. Assistant Dennis is now organizing a party for plane-table duty near Winyah Bay, in Section V.

Hydrography of Nassau Sound, Fla.—In connection with soundings which develop the inland water communication between Saint Mary's, Ga., and Fort George Inlet, near the entrance of Saint John's River, Assistant F. P. Webber has completed the in-shore hydrography of the vicinity, so that the work is now continuous to the southward as far as the approaches to the Saint John's. This service was performed with a party in the steamer *Endeavor*, which reached Fernandina on the 27th of December, 1870. Tidal observations were commenced immediately at Fernandina and near Nassau Bar, and were continued as usual for the adjustment of soundings. Many of the points determined in this section previous to the war, along the Saint Mary's, having been destroyed, Mr. Webber was under the necessity of renewing the triangulation partially, so as to join with the southern limit of previous work. South of the Saint Mary's the points were found as they had been left by the triangulation party. Such additional ones as were needed about Amelia Island were furnished by the plane-table party of Assistant Dennis.

Favorable weather was employed in running lines of soundings off-shore from Amelia Island. At intervals unsuitable for such a purpose the boats of the *Endeavor* were occupied in developing

Nassau Sound, and the channels which connect it with Saint Mary's River and Saint John's River. North and south the inshore soundings develop the coast approaches for twenty miles. The depth seaward was determined to a distance of about seven miles.

Mr. Andrew Braid was attached to the party in the *Endeavor*, and conducted the hydrography, during the temporary absence of Assistant Webber, at Cedar Keys, where he made a survey which will be referred to more particularly under the head of Section VII.

On Nassau Bar the depth, as given by this survey, is about eight feet at mean low water. The channel is narrow, and by sailing vessels the bar can be safely crossed only with a fair wind.

Messrs. Dallas B. Wainwright and W. E. McClintock served as aids in the hydrographic party. By their close application the large amount of office-work resulting from the operations afloat was closed at the end of May, when the steamer returned to Baltimore. The statistics of the hydrography near Nassau Sound are as follows:

Miles run in sounding	1,555
Angles measured	10,601
Number of soundings	98,051

The hydrographic party erected twenty-eight signals, and determined forty-seven points by observations on shore. Under Section I reference has been made to the occupation of the party of Assistant Webber during the summer season. His preparations are now in hand for an early return to hydrographic service on the southern coast.

Triangulation south of Matanzas Inlet, Fla.—For the extension of the survey south of Saint Augustine, along the eastern side of the Florida Peninsula, a flat-bottomed vessel was provided last winter by the hydrographic inspector, but it was unfortunately destroyed by the burning of a ship-yard at Baltimore, while being fitted out for service. Thus deprived of the means for insuring the wished-for progress, Assistant J. A. Sullivan proceeded to Saint Augustine in January, and with a small open boat took up the triangulation below Matanzas Inlet. From stations at which the work had been suspended, he advanced the triangulation southward to Braddock's Point by occupying alternate stations on the shores of Mantanzas River. Six points were determined by eight hundred measurements with the theodolite. The work done by Assistant Sullivan and his aid, Mr. W. H. Stearns, terminates at a station near which the inner sea-water channel, which is so distinctive a feature of the coast above Saint Augustine, is interrupted by about twelve miles of swamp and hammock. Difficulties thus presented in the progress of the survey it is hoped may be overcome by pushing in at high water with a flat-bottomed vessel, now ready for the service, and so advancing as far as practicable by the northern end of the swamp; entering afterward at Mosquito Inlet, and making the survey from the southward to join with work at the swampy barrier. Assistant A. M. Harrison is now preparing to take up plane-table work below Saint Augustine, and to extend the detailed survey southward. Mr. Sullivan returned from this section in April. His party was subsequently engaged in Section I.

Hydrography near the Tortugas.—With the steamer *Bibb*, which was refitted in the course of the winter, Acting Master Robert Platt, U. S. N., Assistant Coast Survey, set sail in January, to complete soundings to the northward of the Tortugas, in the Gulf of Mexico. Signals had been left standing for the purpose, but they had all gone down in the hurricane of October, 1870. Some days were occupied in establishing the requisite points of reference, and in restoring the signals. The hydrography was then continued north of the Tortugas and Quicksands, the lines run being extended to distances of twenty-five miles beyond the ten-fathom curve. This work was laid aside in May for special service, which will be referred to presently. Acting Master Platt was again on the working ground before the end of that month. After completing the hydrography of the Quicksands, he made a close survey of a large bank about four miles to the northward. This, which is parallel with the Quicksands, he has called the *New Ground*. Several spots were found on it with only eight feet of water, and on the north side of the bank the water shoals very suddenly from ten fathoms to less than ten feet. The New Ground is composed of large coral rocks, sand, and grass. Iron buoys, lent by the light-house inspector at Key West, were temporarily used as reference-marks while soundings were in progress in the vicinity of the Quicksands. The statistics of that work are as follows:

Miles run in sounding	746
Angles	1,695
Number of soundings	6,950

Under instructions given on the 1st of May, Acting Master Platt took in tow the ship *Raleigh*, then at Key West, having on board the cable of the International Ocean Telegraph Company. The *Raleigh*, drawing eighteen and one-half feet, and consequently unable to pass by the Northwest Channel from Key West, was towed by the steamer *Bibb* around the Quicksands, and through the Rebecca Channel. On the passage to Punta Rasa, (Charlotte Harbor, Fla.,) the vessels met strong head-winds and a heavy sea. Fortunately the weather changed. Under very favorable conditions the cable was started at Punta Rasa, and successfully laid in a straight course southward and by the shortest route to Key West. On the night of the arrival of the *Bibb*, with the telegraph-vessel in tow, (20th of May,) the United States gun-boat Nipsic parted her chains in a heavy squall and went ashore. Receiving notice of the disaster at midnight, Acting Master Platt had the steamer *Bibb* in readiness, and when the morning tide served, towed off the Nipsic into deep water. As before stated, the hydrographic work was then resumed and was completed near the Quicksands by the end of May. The *Bibb* reached Norfolk on the 11th of June, and was subsequently on service in Section IV.

Messrs. J. B. Adamson and C. L. Gardner served efficiently as aids in this hydrographic party.

The hydrographic party of Lieut. Commander John A. Howell, U. S. N., Assistant in the Coast Survey, is now organized for service with the steamer *A. D. Bache*, one of the new vessels completed within the year. After some trial to determine the working qualities of the steamer the party will run in the course of the winter, lines of deep-sea soundings in the Gulf of Mexico, within the limits of this section. The officers detailed for duty in the party of Lieutenant Commander Howell are Masters W. H. Jaques, E. S. Jacob, Richard Rush, and W. L. Field.

SECTION VII.

GULF COAST AND SOUNDS OF WESTERN FLORIDA, INCLUDING THE PORTS AND RIVERS. (SKETCH No. 8.)

Hydrography of Cedar Keys, Fla.—In March Assistant F. P. Webber left his hydrographic party, then at work near Nassau Inlet, on the eastern coast of Florida, under charge of the senior aid, and crossing the head of the peninsula by railroad, accompanied by Mr. D. B. Wainwright, he made an examination of the present capacity of the principal channel at Cedar Keys. Finding the marked ends of the base, but none of the adjacent stations, Mr. Webber determined eight additional points with the theodolite, and then sounded from the railroad-wharf through to a point about a mile below Sea-Horse Key. He found ten and twelve feet in the middle of the channel at mean low water. The channel is narrow, and needs permanent marks, those now in place being liable to destruction in every gale. The hydrographic work at Cedar Keys is represented by the following statistics:

Miles run in sounding	55
Angles measured	740
Number of soundings	7,477

The subsequent operations of the party of Assistant Webber have been described under the head of Section I.

Hydrography of Saint George's Sound, Fla.—For the hydrographic work required in Saint George's Sound a party was organized under charge of Sub-Assistant Horace Anderson, and sailed from Baltimore, in the schooner *Silliman*, on the 16th of January. The vessel was delayed on the passage southward. In a heavy sea off the Frying-Pan Shoals, the shackles at the mast-head gave way, and the standing gear came down on deck; but by great exertions the masts were saved, and the schooner safely reached Savannah, where she took on board the working-boat intended for service in the Gulf. By reason of light winds after leaving that port the party did not land at Apalachicola until the 13th of February. Work was commenced without delay. The chief of the party and his two aids, Arthur F. Pearl and George W. Bissell, were young, strong, and active, and the crew was thoroughly efficient. Under these and other favorable conditions work was continued

until the evening of Saturday the 25th of February. Next day the aids, at the close of church-service, left Apalachicola in the sail-boat, with four men, to return to the schooner *Silliman*, which was at anchor about four miles from the town. By a very sudden squall of wind at 1 p. m. the boat was upset, and all on board were drowned. The bodies of the aids, and of two of the crew, were found in the course of the week following, and were buried at Apalachicola. My sense of the loss sustained by the survey in the death of the two hydrographic aids has been expressed elsewhere in this report. Of the boat's crew that perished with them, James Scott was shipped at Baltimore; the other three, Henry Austin, Joseph P. Ridley, and James Anderson, belonged to Apalachicola.

Sub-Assistant Anderson, having discharged the sad duties which devolved upon him by this disaster, resumed work, and extended the hydrography of the sound from Bulk-head Point eastward to Royal Bluff. His survey develops many sand-bars and oyster-beds in the eastern approach to Apalachicola. There is, however, a three-fathom channel from the eastward as far in as the bulk-head, where the depth on the bar, which extends across the sound to Cat Point, lessens to seven feet, and where it is frequently less than six feet. The tidal observations made in April and May showed the effect of winds, and that a rise and fall of about eighteen inches might be regarded as the average.

Mr. R. B. Palfrey joined the party as aid on the 1st of April, and is warmly commended in the report of Sub-Assistant Anderson for untiring efforts to repair, as far as possible, the untoward circumstances that marked the early progress of the work. The following is a synopsis of statistics:

Miles run in sounding	310
Angles measured	1,090
Number of soundings	25,048

On the 22d of May the hydrographic party left Apalachicola in the schooner *Silliman*. During the summer Mr. Anderson was engaged in service in Section I. Mr. Palfrey was at the same time on field-duty in Section II. The vessel is now in readiness to continue the hydrographic survey near Apalachicola.

Measurement of base-line and azimuth at Saint Joseph's Bay, Fla.—Under the next head mention will be made of the general occupation of the party of Assistant S. C. McCorkle during the winter of 1870–'71 in this section. Azimuth determinations being needful at two sites on the Gulf coast, the vessel to be used in triangulation was relied on to afford also transportation for the party and instruments of Assistant Mosman. In February, when the observers were ready for service at Eagle Harbor, Assistant McCorkle made his arrangements conformable to the requirements of the astronomical party, and at the same time measured the base upon which his triangulation of Saint Joseph's Bay depends. The ends of the line were connected in the usual way with the adjacent triangulation points by the measurement of horizontal angles. The position of the base-line is shown on the progress sketch of the section. Sub-Assistant H. M. De Wees assisted in the measurement.

Assistant A. T. Mosman, under arrangements made with Assistant McCorkle, was landed from the schooner *Torrey* at Eagle Harbor, on the 5th of February. All needful aid was given by the triangulation party in mounting the astronomical instruments, and in erecting a shelter to protect them from injury. With theodolite No. 16 Mr. Mosman and his aid, Mr. Edwin Smith, observed for azimuth on four favorable nights preceding the 14th of the month, and recorded seventeen sets of observations. In order to connect the azimuth-station with points in the triangulation of Saint Joseph's Bay, horizontal angles were measured by twelve sets on three days. The time was determined by seventeen sets of observations made on five days with the sextant and artificial horizon.

This work is noticed in its proper geographical order, but was preceded by similar duty at Saint Andrew's Bay, as will be mentioned presently.

Triangulation of Saint Andrew's Bay, Fla.—Last year the eastern and northern arms of this bay were included in the operations of Assistant McCorkle. In order to complete the triangulation, he returned to Apalachicola early in December, 1870, expecting to move immediately westward with the schooner *Torrey*, which was under his charge for the use of his party. But preparations for sailing had been delayed by the sudden death of the ship-keeper. The vessel of necessity

was refitted under the immediate supervision of Assistant McCorkle, and could not reach the working ground in Saint Andrew's Bay until the night of the 26th of December. On the passage Assistant Mosman was landed at Davis' Point, (Sketch No. 8,) the place of work for the season including also the determination of azimuth. Sub-Assistant H. M. De Wees accompanied the party into West Bay for topographical service.

After erecting signals on the shores of the bay, horizontal angles were measured as usual with the theodolite. Four of the lines of sight required to be opened by cutting through the woods, in order to bring the signals into view. Sketch No. 8 shows the scheme of triangulation.

The field statistics are:

Signals erected	19
Angles measured	97
Number of observations	1,872

Assistant McCorkle co-operated in the work assigned to Assistant Mosman by transferring his party when needful, and affording help in procuring lumber at Apalachicola. His party aided also in the erection of the camp, and in mounting the astronomical instruments at Davis' Point.

The latter part of the season in this section was employed by Mr. McCorkle in a reconnaissance along the coast toward Choctawhatchee Bay. Beyond Saint Andrew's Bay to the westward the country is heavily wooded. Many swamps were passed making in at right angles to the shore of the Gulf of Mexico. The difficulty of extending the triangulation is great, but possibly the obstacles presented in this stretch of about forty miles may be lessened by examining the ground which intervenes between the upper waters of Saint Andrew's Bay and those that enter into Choctawhatchee Bay. As yet no well-defined roads are laid out, but a party has been organized for such service as may be practicable in the development of this region.

Late in April the schooner *Torrey* was laid up at Apalachicola in the charge of a ship-keeper. Assistant McCorkle then passed northward, and during the summer and fall was occupied in field-work in Section II.

Before leaving Saint Andrew's Bay the base-line upon which the triangulation depends was carefully remeasured, as also the angles connecting it with the triangulation. Sub-Assistant De Wees co-operated in this service.

Latitude and azimuth at Saint Andrew's Bay, Fla.—At Davis' Point the astronomical instruments intended for the determination of latitude and azimuth were landed from the schooner *Torrey* late in December, 1870. Before leaving for the prosecution of routine work, aid was given by the triangulation party in the schooner for setting up tents and securing the instruments in their places. Everything being in readiness, Assistant Mosman commenced astronomical observations on the 4th of January, and employed every clear night until the 17th, seven being occupied in observing on twenty pairs of stars with zenith telescope No. 6 for latitude. Time was determined on nine nights by observations on sixty-four stars with transit No. 12. Twenty-four sets of observations were made on six nights for azimuth with theodolite No. 16; and by measuring horizontal angles on five days, the azimuth-station was connected with the triangulation of Saint Andrew's Bay.

Mr. Edwin Smith served as aid and recorder in the astronomical operations. Assistant Mosman left Apalachicola on the 20th of February, for service in Section IV. He was afterward engaged in Section III, and toward the end of the season co-operated in astronomical work in Ohio and Kentucky, further mention of which will be made before closing notices of work in Section VII. Duplicates of all the records kept by Assistant Mosman on the Atlantic and Gulf coasts have been deposited in the office, together with the field computations for latitude, azimuth, and magnetic observations.

Topography of Saint Andrew's Bay, Fla.—The plane-table work outstanding at Saint Andrew's Bay when the season opened included some details additional to the survey which had been made, in the preceding year, of the eastern and northern arm, and the survey of the western part of the bay. As already mentioned, the triangulation there was taken up by Assistant McCorkle early in January. Following in order as points were furnished, Sub-Assistant De Wees, after filling in supplementary details to the eastward, traced the shore-line of the western arm, including the

bayous and creeks which empty into it, and thus made the field-work at Saint Andrew's Bay complete. The plane-table sheet represents West Bay as bounded by marsh generally, in some places quite narrow, but in others having a width of a quarter of a mile. The marsh is backed by pines and underbrush with a few live-oaks and some palmetto. Light-draught vessels can pass through the western arm of Saint Andrew's Bay. The shores, however, with the exception of occasional hummocks, are so low and swampy for some distance inland as to be impassable. Sub-Assistant De Wees closed work in May, with the following return in statistics for this section:

Miles of shore-lines surveyed	47½
Miles of bayous and creeks	108
Area, (square miles)	47

After discharging the plane-table party Mr. De Wees returned to the office and was assigned to duty on the coast of Maine, as mentioned under Section I. He is now under instructions for service in Section IV.

Triangulation, topography, and hydrography of Santa Rosa Sound, Fla.—The Gulf coast between Choctawhatchee Bay and Pensacola Bay, a distance east and west of about forty-five miles, has been thoroughly surveyed by a party under the charge of Sub-Assistant H. G. Ogden. Santa Rosa Sound connects the waters of the two bays, and is separated from the Gulf by a low sandy island fifty miles long. The width of this barrier at the average is about a quarter of a mile. Santa Rosa Sound itself, stretching east and west, varies in breadth, being two miles across toward the western end, where it joins Pensacola Bay, but is less than three hundred yards wide near its entrance into Choctawhatchee Bay. Field operations were commenced late in December, 1870, and closed on the 16th of the following May.

Sub-Assistant O. H. Tittmann, who was attached to this party, made the needful triangulation, starting from two stations, (Fort Pickens and the navy-yard,) which had been occupied previously in the survey of Pensacola Bay. Going eastward he set up signals, and occupied alternately many stations on the north and along the south shore of the sound, and extended his triangulation into Choctawhatchee Bay. The western part of that body of water was also included in the survey of this year, and also East Pass, which is an outlet from Choctawhatchee Bay into the Gulf of Mexico.

The conditions being unfavorable in some places along the sound for extended lines in the triangulation by reason of the intervention of trees and sand-hills, great care was taken in the determination of horizontal angles, thirty six measurements being recorded for each angle. Additional to the arrangement in quadrilaterals, angles were measured from their stations to connect with them any signals that might be visible in the adjoining quadrilaterals. The scheme of triangles shown in the progress sketch, and the statistics of the work, are evidences of untiring patience, and the results are highly creditable to the members of the party.

The topography of Santa Rosa Sound was commenced by Sub-Assistant Ogden early in February, at a point eleven miles from Fort Pickens. Three sheets were filled in going eastward, the last taking in the western part of Choctawhatchee Bay with Garnier Bayou, Five-Mile Bayou, and the shores of East Pass, which connects the bay with the Gulf of Mexico. Santa Rosa Island, as represented on the plane-table sheets, is covered in spots with grass and pine trees. Patches of marsh are met in a few places along the inside shore. The sand-hills on the island are generally isolated, but in a few instances they occur as ridges. Along the Gulf shore, however, a nearly continuous ridge of sand from five to ten feet high, and covered with grass, presents a barrier so effectual that the island has nowhere been cut through by the waters of the Gulf. In many places the ridge shows like an artificial structure, so regular are the slopes. The topographical survey shows but one break in the entire length of this peculiar sand-barrier.

The mainland, or north shore of Santa Rosa Sound, is mostly swampy to the distance of a quarter of a mile from the water-line, and is covered with a growth of pines, among which are a few live-oak trees. At a few places hard land skirts the sound, but firm ground is continuous along the Narrows and eastward to Choctawhatchee Bay. As far as yet surveyed the bay-shores are dry, and have elevations of twenty or thirty feet.

Soundings were commenced at Deer Point, the eastern limit of Pensacola Bay, and from thence eastward the channel of Santa Rosa Sound was thoroughly developed to its connection with

Choctawhatchee Bay, the western part of which and its bayous, as well as East Pass, were included in the hydrographic operations.

Off Deer Point, at the western end of the sound, Sub-Assistant Ogden found a depth of twenty-five feet. Ten miles eastward the depth in Santa Rosa Sound is no more than eighteen feet. Twenty miles east of Deer Point the depth is only twelve feet, and there occurs the first bar across the sound, the least depth being eight feet. Going farther eastward and through the Narrows the channel is tortuous, with frequent bars, four of which are used as crossing-places, the depth being only four or five feet, but there are intervening depths of more than twenty feet.

On the bar of East Pass the sounding party found a depth of about eight feet, and somewhat more through the pass into Choctawhatchee Bay. The current was very strong through the pass.

Tides were observed at five places on the shores of Santa Rosa Sound by the party of Mr. Ogden, and for mean low water all results were referred by simultaneous observations to the old tidal station at the wharf of Fort Pickens. In the sound the observed tide is very small, and Mr. Ogden states that in Choctawhatchee Bay the water-level seems to be governed entirely by the wind.

Before leaving this section the party remeasured the angles of the triangulation going westward across Pensacola entrance, and from Fort Pickens verified the measurements which determine the positions of Fort McRae; those of the beacons, inside and outside of the entrance to the bay; the position of the light-house, and that of the navy-yard wharf.

Sub-Assistant Ogden commends for energy, care, and precision, the work of his associate Sub-Assistant Tittmann, and also the services of his aid, Mr. S. N. Ogden, and of the sailing-master of the schooner *Agassiz*, which was used in the surveying operations. Afield and afloat the party developed an aggregate area of one hundred and ten square miles. The particulars of work are as follows:

Signals erected	63
Stations occupied	52
Angles measured	293
Number of angular measurements	9,568
Miles of shore-line traced	150
Miles of roads	13
Miles run in sounding	439
Sextant angles	3,591
Casts of the lead	32,993

The records connected with this work have been duplicated as usual. During the summer Mr. Ogden was engaged in Section II, and Mr. Tittmann at the same time in Section VIII. The schooner *Agassiz* was laid up at Mobile, to be in readiness for service in the prosecution of the survey of the Gulf coast eastward of Choctawhatchee Bay. If the present winter proves favorable it is hoped that the survey westward of Saint Andrew's Bay may be joined with the work here described.

Latitude and longitude of Cleveland, Ohio.—In accordance with the proviso in the appropriation bill authorizing determinations of latitude and longitude in the interior States of the Union, Assistant George W. Dean was directed in the latter part of July to make arrangements for occupying important points in Ohio and Kentucky. He was joined on the 10th of August by Assistant Edward Goodfellow, who proceeded with suitable instruments to Cleveland, and there established a temporary astronomical station near the Marine Hospital. Unfavorable weather in September made it impracticable to determine the longitude, but in the course of the following month clock-signals were successfully exchanged on five nights with an observer at Cambridge observatory for longitude.

Assistant Goodfellow determined the latitude of the station at Cleveland by 126 observations on thirty pairs of stars; and the local time and instrumental corrections by 204 observations on thirty-six stars.

The magnetic declination was determined by Mr. Goodfellow from observations on three days; and the intensity from three sets of vibrations and two sets of deflection. Four days were employed in ascertaining the magnetic dip.

Observations were completed at Cleveland on the 16th of November. Mr. Goodfellow then transferred the instruments to Falmouth, one of the stations occupied in Kentucky, in August, 1869, for observing the total solar eclipse.

Latitude and longitude of Columbus, Ohio.—By permission of Governor Hayes, the astronomical station was established near the court-house at Columbus. Assistant Dean exchanged clock-signals with Cambridge on six nights between the 23d of September and the middle of the following month, recording in that period 123 observations on 26 zenith and circumpolar stars. The determinations were made with a 46-inch transit, (No. 6,) a break-circuit chronometer, and the spring governor-chronograph No. 2. Mr. Dean's computation gives for the State-house at Columbus a position nearly fourteen seconds in time, corresponding to more than three statue miles, farther east than former determinations.

Observations for latitude were made at Columbus by Assistant A. T. Mosman on six nights, closing with the 9th of October. The record shows 165 measurements on 29 pairs of stars. Two sets of observations were made for the micrometer value.

The astronomical station at Columbus was referred by geodetic measurements to the center of the dome of the State-house.

Prof. Joseph Winlock, director of the Harvard College observatory, Cambridge, Mass., co-operated with the parties in the determinations for longitude at points in Ohio and Kentucky. The president of the Western Union Telegraph Company, Hon. William Orton, extended as heretofore all the facilities needful in the telegraph-work for longitude.

Latitude and longitude of Oakland, Ky.—A station was occupied at Oakland during the solar eclipse which was total in that vicinity in August, 1869. At that time the telegraph-line now in use had not been established. As several other points were to be occupied in the course of the present season in the Western States, the opportunity was taken to determine the longitude and latitude of the eclipse-station, near Oakland. When the purpose was made known the officer in charge of the Western Union Telegraph Company's line passed a loop to the observing station at the request of Assistant Mosman, and placed at his disposal the facilities needful for exchanging clock-signals with an observer at Cambridge observatory, in Massachusetts. Signals were successfully observed on the nights of the 4th, 5th, 6th, and 11th of November.

At intervals on the same nights on which observations were recorded for longitude, Mr. Mosman determined the latitude of the eclipse-station, using 24 pairs of stars and noting 109 observations.

At the same station Assistant Mosman occupied three days in observing the magnetic declination, dip, and horizontal intensity. Having completed the work required at Oakland, the instruments were packed on the 14th of November and dispatched to Shelbyville.

Latitude and longitude of Shelbyville, Ky.—Late in July, 1869, the latitude was determined at Shelbyville, at a station selected for use in the following month by one of the parties under my direction for observing the solar eclipse, which was total in that vicinity. At that time telegraph wires had not been extended so as to admit of special observations for longitude; hence the station was marked and the desired determination was held in reserve until the present season, when similar service was to be undertaken at other places in the section. Telegraphic facilities meanwhile had been extended to the neighborhood of Shelbyville.

Assistant Mosman having made arrangements at Shelbyville in the latter part of November, was joined by Assistant Dean. Clock-signals were exchanged, on six nights, with an observer at Harvard College observatory, under circumstances favorable for determining the difference of longitude. Observations were made in the usual way between the observers for ascertaining personal equation.

After completing the work at the station near Shelbyville, Assistant Dean took charge of the records for computation. Assistant Mosman and his aid, Mr. Smith, are now making arrangements for astronomical duty in Section V.

At all the stations occupied in Ohio and Kentucky, the magnetic elements were determined. Field-work was closed at Shelbyville on the 11th of December,

SECTION VIII.

GULF COAST AND BAYS OF ALABAMA AND THE SOUNDS OF MISSISSIPPI AND OF LOUISIANA TO VERMILION BAY, INCLUDING THE PORTS AND RIVERS. (SKETCH No. 9.)

Topography of Chandeleur Sound, La.—In May, after closing operations which will be described under the next head, Assistant C. H. Boyd made a plane-table survey along the west side of Chandeleur Sound, continuous with his work of last year, which terminated in the upper part of Isle au Breton Sound. This survey defines the broken ground and patches lying about ten miles north and south in the vicinity of Live-Oak Bayou. The statistics will be included with details which occupied the party during the preceding month of the working-season in this section. Messrs. Joseph Hergesheimer and C. H. Van Orden aided in the topographical survey.

Triangulation, topography, and hydrography of Mississippi River, La.—Assistant Boyd resumed work at Grand Prairie, above Fort Jackson, late in December, 1870, with a party in the schooner Hall. Twenty miles of the course of the Mississippi are included in the operations of this season. The survey was suspended on the last of April at Point La Hache, which is about sixty miles from the light-house at South Pass, on the Gulf of Mexico. In selecting stations for carrying the triangulation up the river, Mr. Boyd met many difficulties, lines of sight to points otherwise favorable for the work being intercepted by buildings or by clumps of trees. The theodolite, moreover, at nearly every point was, of necessity, placed on a platform of timber, to give stability on the soft prairie and to insure the line of sight. Another disadvantage was that arising from the fogs that prevail morning and evening during the greater part of the year. These are attributable to the meeting of the belt of cool air along the river with the warmer air of the Gulf coast. Without a more expensive outfit the currents, as observed at two stations in the river, must also be impediments in field-work, which includes both banks, the current at one place being five miles per hour.

The topographical survey by Assistant Boyd and his aids, Messrs. Hergesheimer and Van Orden, includes both banks of the Mississippi within the limits of the triangulation, and such bayous as were found within three miles of the river. On the eastern side the bayous were traced to their connections with Isle au Breton Sound.

In prosecuting the hydrography Mr. Boyd found the depth in the Mississippi much less than is usually reported, averaging at the most about twenty fathoms, instead of thirty, in the stretch between Point La Hache and Fort Jackson. Before leaving the section arrangements were made for keeping up, during the year, a series of tidal observations at the quarantine-station. Near the upper limit of his work Assistant Boyd selected and marked the ends of a base-line, about two and a quarter miles in length. This will be measured by his party in the coming winter. The statistics of the survey of this year on the Mississippi are as follows:

Signals erected	30
Stations occupied	25
Points determined	36
Horizontal angles measured	199
Number of observations	4,008
Miles of shore-line traced	258
Miles of roads traced	39
Area of topography, (square miles)	118

Fifteen hundred soundings were made within the topographical limits. The tidal record was kept up during four months. All the registers of observations and the resulting sheets of work have been received at the office.

Assistant Boyd, during summer and autumn, conducted a field-party in Section I, and is now on his way to resume the survey of the Mississippi.

Hydrography of Lake Pontchartrain, La.—Assistant J. S. Bradford reached New Orleans on the 10th of December, 1870. He at once took charge of the schooner *Varina* and a small tender, the *Barataria*, which had been laid up at the end of the previous season in Pearl River. The vessels were refitted without delay, and the party was in working order early in January. Thence onward soundings were prosecuted in Lake Pontchartrain until the 8th of April, when the limits of the

shore-line survey were filled. The hydrography comprises the eastern part of the lake somewhat beyond Ragged Point, on the north shore. On the south side soundings extend as far as the light-house which stands on the lake-shore north of New Orleans. In this and other service in the section, mention of which will be made under separate heads, Assistant Bradford was aided by Mr. C. P. Dillaway. The statistics of work in Lake Pontchartrain are:

Miles run in sounding	571
Angles measured	1,056
Number of soundings	41,753

Deep-sea soundings off the Mississippi delta, La.—Assistant Bradford, after closing work in Lake Pontchartrain, laid up the launch *Barataria* at Fort Pike and reached Pass á Loutre with the schooner *Varina* on the 22d of April. Stormy weather prevailed until the end of that month, but as soon as practicable deep-sea soundings were begun near Southwest Pass and South Pass, and lines were run at all favorable intervals until the 18th of May, when the *Varina* was required for special hydrographic work in the Gulf of Mexico, westward of the delta, as will be further mentioned under a separate head. The lines run in the Gulf, near the delta, make an aggregate of a hundred and seventy-five miles, and depths were determined at six hundred and eight positions. Mr. Dillaway efficiently aided in this and in the subsequent operations of the party. Mr. T. J. Lowry, the junior aid, having recovered from illness which seized him on his arrival in the section, also served acceptably.

Hydrography of Trinity Shoal.—This was the concluding work of Assistant Bradford in this section. The shoal lies in the Gulf of Mexico, about one hundred and fifty miles westward of the Mississippi delta. In order to determine the proper site for a light-house the vicinity was sounded by the hydrographic party in the schooner *Varina* in the latter part of May. Mr. Bradford developed the ground in question by upward of a thousand casts of the lead, and sent to the office a chart sufficient for the present requirements by the Light-House Board.

Early in June the schooner *Varina* was laid up in the Mississippi, at the head of the passes. Assistant Bradford then reported at Washington, and subsequently prosecuted hydrographic duty in Section I.

Geodetic points in Illinois and Missouri.—In further application of the sum voted for determining points in the interior, to serve as the bases of surveys that, when made by the several Western States, will be in true geographical relation to the coast, I made a reconnaissance in June last of the region about Saint Louis, in Missouri. Assistant Richard D. Cutts accompanied me in this service, and to his large experience in field operations I am indebted for an early decision on the feasibility of occupying intervisible stations for triangulation within an area of about a thousand square miles in Illinois and Missouri. Late in June Mr. Cutts returned to the Atlantic coast to conduct the operations of his own field-party in Section II, mention of which has been made under that head.

The locality having been selected for the determination of geodetic points, instructions were given to Assistant R. E. Halter to organize his party and to lay out a scheme of triangulation across the Mississippi River extending to the westward in Missouri and to the eastward in Illinois, keeping in view the determination of spires and other prominent objects as additional points for the use of the local authorities. The determination of an astronomical azimuth and the selection of a site for a base and its preliminary measurement were also included among his duties. Sub-Assistants William Eimbeck and O. H. Tittmann, both residents of Saint Louis, and possessing serviceable information of the country in its vicinity, were detailed to assist in the field.

Mr. Halter reached Saint Louis on the 7th of July. With the necessary outfit and means of transportation the selection of stations was commenced, and was continued until the end of August, when it was deemed advisable to divide the party. Assistant Halter, with Mr. Tittmann, took charge of the work on the Illinois side, and Mr. Eimbeck of the operations in Missouri. The examination was somewhat retarded by excessive heat and haze in July and August, and later in the season by the sickness of each member of the party.

The scheme for the triangulation so far laid out extends, north and south, from a station below Saint Louis to Alton, a distance of thirty miles, and about the same distance, east and west, from

Sugar Loaf, in Illinois, to Kessler's, in Missouri. A site for a base, (see Sketch No. 9,) five miles in length, was selected near the station last mentioned. The longest line is eighteen miles, and the average of the triangle sides about ten miles in length.

Assistant Halter reports that, after reaching the Mississippi Bluffs, in Illinois, his farther progress to the eastward, in the axis of the scheme already established, was impeded by a heavy growth of timber, extending four or five miles before the open country could be again reached; and that he had examined this tract for about twenty-five miles, north and south, without finding any practicable opening. If lines of sight cut through this belt of timber will entail considerable expense, the alternative will be to extend the scheme of triangles down the river to the high lands which overlook it.

On the Missouri side the country was found more broken, and although considerable cutting had to be done, a scheme of triangles was found practicable.

After selecting the stations and erecting eleven signals, the measurement of horizontal angles was commenced by Assistant Halter and Sub-Assistant Eimbeck. The former occupied and observed the angles at the stations of Dryer and Clark's Mound, in Illinois, and the latter at one of the stations in Missouri.

The preliminary measurement of the base was made by Mr. Halter late in November. Mr. Eimbeck determined the azimuth, closing operations for the season on the 1st of the present month. The winter being very unfavorable for field-work in Missouri, the different members of the party were assigned to duty on the lower sections of the coast.

With a view to make the work now in progress in Illinois and Missouri inure as early as possible to the advantage of the States, the points determined by the triangulation party will be connected with adjacent section-corners of the surveys which have been already made by the General Land-Office.

SECTION IX.

GULF COAST OF WESTERN LOUISIANA AND OF TEXAS, INCLUDING BAYS AND RIVERS. (SKETCH No. 9.)

Hydrography of Matagorda Bay and Espiritu Santo Bay, Tex.—The party of Sub-Assistant F. D. Granger reached Indianola on the 20th of December, 1870, and before the close of that month commenced the hydrography of Lavaca Bay. The schooner *Stevens* was used in this service. By the end of January following, soundings were completed in the bay, including also its branches, known as Keller's Bay, Cox's Bay, and Chocolate Bay, the last in the immediate vicinity of the town of Lavaca. Five other sheets were filled in the course of the season. Trespalacios Bay was sounded out thoroughly in February. The resulting sheet shows that the course of the channel has changed in recent years, and that the depth has decreased to five feet. In Carankaway Bay, which is another of the branches of Matagorda Bay, soundings were completed on the 23d of March. Among the changes at the head of this bay, Mr. Granger notes the washing away of a small island at the mouth of Carankaway River. From the careful soundings made below Palacios Point in the latter part of March and early in April, it is shown that Half-Moon Reef is gradually projecting into the body of Matagorda Bay. The light-house is now in four feet water, but the extremity of the shoal, which was at the light when erected, is now one hundred and fifty metres beyond the light-house. After sounding at the entrance to Matagorda Bay, in the vicinity of Decros Point, the party moved into Espiritu Santo Bay, and there continued soundings until the 6th of May, when work was suspended. At that date the hydrography of the bay had been extended to Vanderveer's Island. Careful tidal observations were made during the entire season by Sub-Assistant Granger and his aid, Mr. F. W. Ring. The record shows the tides of January at Lavaca, day and night tides for February and March at Half-Moon Reef, and a series observed at Saluria Bayou while the work was in progress at Matagorda entrance and in Espiritu Santo Bay. Comparisons were taken by simultaneous observations at the several stations, the plane of reference used for the reduction of soundings being deduced from observations at Half-Moon Reef. The general statistics of work are as follows:

Miles run in sounding	1,256
Angles measured	6,993
Number of soundings	72,433

The six hydrographic sheets containing this work have been deposited in the office.

Sub-Assistant Granger and Mr. Ring were on service during summer and autumn in Section II, and are now in readiness for resuming hydrographic duty on the coast of Louisiana.

Latitude and longitude of Chetopa, Kans.—Early in the summer collateral service in the Department of the Interior called for the determination of the longitude of a point on the southern boundary of Kansas near the 95th meridian, west, for the purposes of the United States land-surveys. Contractors who had engaged to subdivide parts of Kansas and Indian Territory into land-sections were required by the Department to make the intersection of that meridian with the State boundary a point of departure, and by advice of the Commissioner of the General Land-Office the temporary service of one of our observers was requested. The contractors for the land-surveys having engaged to defray the incident expenses, the assistant in charge of the office provided instruments immediately, and the longitude observations were committed to Prof. R. Keith, then in service as a computer for the Coast Survey Office.

The determination was made by exchanging time signals from the nearest telegraph-station with an observer at Saint Louis, the longitude of a station there having been accurately ascertained in previous operations. By observing transits and comparing chronometers by telegraph on three nights, the longitude of Chetopa, Kansas, was determined to be $1^h\ 12^m\ 12^s.37$, west of Washington, with an uncertainty of $0^s.07$. At Saint Louis the requisite observations were made by Sub-Assistant W. Eimbeck. These included the determination for personal equation between the observers, which was found to be $0^s.16$. Each observer noted time by his own chronometer on the same night while observing stars of about the same declination, the chronometers being at the same time compared by coincidence of beats. The whole series of observations was formed into equations of condition, assuming two chronometer corrections, one for each observer.

By observing transits in the prime vertical, Professor Keith found for the latitude of his station at Chetopa 37° 02′ 13″.0, north.

This work was greatly facilitated by the courtesy of the railroad and telegraph officials. The Western Union Telegraph Company, with accustomed liberality, gave the use of the line for determining the longitude.

SECTION X.

COAST OF CALIFORNIA, INCLUDING THE BAYS, HARBORS, AND RIVERS. (SKETCH No. 10.)

Geographical reconnaissance between San Diego and Panama.—Preparatory to the undertaking of the hydrographic reconnaissance for which the steamer *Hassler* is now in transit by the way of Cape Horn, Assistant George Davidson has connected San Diego with San Francisco by a full series of telegraphic observations for longitude, thus giving a well-determined starting-point for the reconnaissance. From his triangulation-stations in San Diego Bay he has also determined the position and elevation of readily-recognized mountains on the coast of Mexico.

In March Sub-Assistant Gershom Bradford was instructed to make a survey of the entrance and bay of Magdalena, on the coast of Lower California, and for this duty the surveying schooner *Marcy* was assigned to him. On his passage from San Francisco Mr. Bradford stopped at the island of Guadalupe, verified its position, and determined its elevation. The height was found to be 2,570 feet.

The triangulation of the bay of Magdalena was founded on a measured base of 4,414 metres. Points on the shores were determined by sextant-angles with sufficient accuracy for the hydrographic work. The longitude of a station was determined by chronometers brought from San Francisco, and the azimuth of one of the lines of the triangulation by observations on Polaris. Long and continuous series of tidal observations were made at two stations, and some current data obtained. The hydrography was carefully executed, and great changes are indicated by comparison with previous surveys. Special examination was made for a reported rock off the south point of the entrance to the bay, but nothing appeared to indicate its existence.

The following statistics exhibit the work executed between March 9 and June 30:

Signals erected	52
Stations occupied	33

Number of observations	601
Miles of shore-line surveyed	90
Miles run in sounding	1,020
Angles measured	7,470
Number of soundings	31,719

The records of the work are comprised in twenty volumes. Charts resulting from the hydrographic work have been received at the office.

Sub-Assistant Bradford was aided in this special service by Mr. Westdahl, the sailing-master of the schooner *Marcy*. After returning to San Francisco the party sailed to make search for the Falmouth Shoal, as will be hereafter noticed.

Mr. Davidson has furnished a view of the entrance and approaches to Magdalena Bay. Before leaving that vicinity he determined the elevation of several of the mountains of Margarita Island, which forms the south side of the entrance.

The bay of Magdalena, as described by Assistant Davidson, is one of the most spacious on the Pacific coast, rivaling the Gulf of Fonseca and the bay of San Francisco. The entrance is three miles in width, has no bar, carries a depth of twenty fathoms, and has bold headlands rising from deep water to a height of about one hundred feet. The height increases as they recede. The northern head is marked by two rocks like beacons, the outer one being much the larger. On making the entrance the conical peak of Mount Isabel is seen as a prominent landmark, and is easily recognized. Margarita Island, forming the south point of the entrance, is very bold, high, and broken. In the clear weather which prevails on this part of the coast there is no difficulty in making the entrance. The prevailing wind is from the westward, and blows directly in, but not too strong for a good working breeze in going out. There is another entrance to the bay at the southern extremity of Margarita Island, but it is long and made tortuous by sand-shoals, and has less than three fathoms of water. This channel is never used. The drawback to Magdalena Bay is its large expanse and regular form, which oblige vessels to shift their anchorage with changes of the wind. On the west side the shores are bold, rugg ed, and covered with cacti. Deep water is found close under the shores. The eastern shores are sandy dunes, in part covered with cacti. Extensive margins of shoal water mark that side of the bay. There is an absence of fresh water on the shores generally, and a very scant supply of wood.

Off-shore hydrography—The steam-vessel requisite for prosecuting off-shore soundings in this section sailed from Boston on the 4th of December instant, and is now on her course toward San Francisco by the way of Cape Horn. Commander Philip C. Johnson, U. S. N., assistant in the Coast Survey, and chief of the hydrographic party in the *Hassler*, is authorized to make incidental researches during the voyage by deep-sea soundings, and other observations, which will postpone for a short period the commencement of regular service on the coast of California. It is expected, however, that some advance may be made before the close of the present fiscal year in the development of dangers in the navigation of the Pacific coast between San Diego and Panama. This will be the first service of the party in the steamer *Hassler* after reaching the section.

Commander Johnson is assisted by Lieut. Commander C. W. Kennedy, Lieut. M. S. Day, and Masters H. B. Mansfield and E. W. Remey.

In the introduction of this report I have explained the general character of the marine researches which will be made by the officers of the party while the steamer is in the course of transfer to her destined station for general hydrographic duty.

Longitude and triangulation of San Diego, Cal.—For the determination of the difference of longitude between San Francisco and San Diego, Assistant Davidson occupied an astronomical station at San Diego, and by the liberality of the Western Union Telegraph Company, had a loop of their main line to San Francisco carried to the temporary observatory. Mr. S. R. Throckmorton, jr., aid, at the same time occupied the station in Washington Square, in the last-named city. This work was successfully accomplished during the month of May. Assistant Davidson's observations embrace twelve double altitudes of the sun, two hundred and ninety-five transits of seventy-eight stars on nineteen nights, and the exchange of clock-signals on eleven nights. The meridian instrument No. 1, Frodsham break-circuit chronometer, 3479, and the Hipp chronograph, 3753, were

used for this determination. Records of the observations in duplicate, and the chronograph-fillets, have been received at the office. Mr. Davidson was aided by Mr. H. I. Willey.

At the request of the trustees of the city of San Diego, Assistant Davidson established a meridian-line on the peninsula, four miles south of the astronomical station, as a permanent mark of reference for the determination of the magnetic declination, and for the use of the city and county surveyors.

After completing the observations for longitude at San Diego, the observers met at San Francisco, and, for personal equation, recorded seventy transits, on three nights, with six chronograph-sheets.

At Washington Square, in San Francisco, Mr. Throckmorton observed four hundred and twenty-four transits of ninety-five stars, on twenty-five nights, and sent clock-signals on twelve nights. His records, including seventy-one chronograph-sheets, have been duplicated, and are now at the office.

At two of the triangulation-stations, of 1851, in San Diego Bay, angular measurements were made to connect the astronomical station occupied in May, and also the light-house, with the scheme. The principal line of the triangulation Mr. Davidson transferred to two stations not liable to be disturbed by improvements for many years. All the stations were carefully marked. The statistics of this work are subjoined:

Signals erected	7
Stations occupied	5
Angles observed	34
Observations	621

Vertical angles were measured to determine the elevation of the stations; of the Coronados Islands, and of Table Mountain and others, in the vicinity of San Diego.

Near the astronomical station at San Diego, Mr. Davidson determined the magnetic declination, dip, and horizontal intensity by observations continued through three days.

Triangulation and topography of Bahia Ona, Cal.—Assistant Davidson erected three signals on the shores of Bahia Ona, and occupied the stations San Pedro Hill and Point Duma. After connecting the latter with the main triangulation, he determined the position of a station on Santa Barbara Island, where a signal has been erected by Sub-Assistant Chase. At the connecting stations Mr. Davidson observed on five signals by one hundred and fifty observations of six angles; and also recorded twenty double altitudes of eight objects for elevation.

San Miguel Island will be joined in the triangulation next season. To that end a signal was put up at the principal station by Sub-Assistant Forney. The local survey on that island will be mentioned in a subsequent notice.

Before returning to San Francisco Mr. Davidson examined the coast from Point Duma to San Diego with reference to facilities for the development and progress of the triangulation. Besides the surveys of ranchos bordering the coast which were collected in the journey, he added details obtained by special examination. Mr. H. I. Willey aided in the work on the shores of the Santa Barbara Channel.

Early in the winter of 1870 Sub-Assistant A. W. Chase forwarded to the office the records and computations connected with his work of the preceding season near Point Saint George. He then resumed the triangulation and topography from his previous limit of work near Point Vincente, and carried the survey to the main station, West Beach. Part of the topography represents the western end of San Pedro Mountain; other details include the rolling hills which border the coast of the Santa Barbara Channel. The old sea-benches that mark San Pedro Mountain are well exhibited on the topographical sheet.

The following statistics show the work done before Mr. Chase transferred his party to the vicinity of Crescent City for the survey in that quarter, which will be noticed in regular order.

Miles of shore-line traced	11
Area, (square miles)	18

Triangulation and topography of the Santa Barbara Channel and Islands, Cal.—The work near Point Vincente was prosecuted during the winter by the aid of the party. Meanwhile Mr. Chase proceeded to Santa Barbara Island, measured a base of six hundred metres, and covered the island

with a small triangulation for the plane-table survey, which he carried on at such intervals as the generally unfavorable season would permit. The original sheet has been received at the office. Statistics of the work are subjoined:

Signals erected	10
Angles measured	32
Observations	192

The topography represents a fringe along the shore-line, of which five miles are represented on the plane-table sheet. Mr. Chase has given a full description of the outlying dangers, anchorages, &c., of Santa Barbara Island. After closing this duty he returned to his party at Point Vincente.

Assistant Davidson provided a camp for the party of Sub-Assistant Stehman Forney, who was instructed to commence the topography and necessary triangulation of San Miguel Island, the westernmost of the Santa Barbara group. This windward island is peculiarly exposed to continuous fogs and heavy northwest winds, the prevalence of which has marked the present season. Nevertheless, a good return has been made by the party of Mr. Forney. Some of the triangulation-stations were recovered, and a scheme of tertiary triangles was developed to make a good trigonometric connection with the survey of Santa Rosa Island. A whale-boat was employed for this difficult duty. There is no water on San Miguel Island; even the fuel needed had to be brought from the mainland. The following are statistics of work executed by this party:

Signals erected	17
Stations occupied	8
Signals observed	14
Number of observations	1,910
Miles of shore-line surveyed	17
Miles of bluff outline	10
Square miles of topography	24
Topographical signals erected	14

The positions of dangerous rocks lying off San Miguel Island were determined, and marked on the survey. Mr. Forney will continue in the field until he finishes the work on San Miguel Island. His report includes a full description of Cuyler's Harbor.

Assistant W. E. Greenwell has continued the survey of the coast of California westward from Point Pelican, near Santa Barbara, and has reached a point midway between Santa Barbara and Point Conception. The season was unfavorable there, as elsewhere on the western coast. At the end of August Mr. Greenwell was taken dangerously ill, and, after much suffering, was constrained to discharge his party for the season.

The topography is based upon the tertiary triangulation of previous years, and has been carried to the limit of the preliminary work near Gaviota Pass. It is comprised on two sheets, showing details along the southern flank of the mountain range, which here crowds down close to the shores of the channel. The country is rolling, partly wooded, and in some localities settled and improved. The following statistics show the work executed by this party:

Miles of shore-line traced	24½
Miles of bluff outline	14
Miles of creeks surveyed	9
Miles of roads surveyed	32
Area, (square miles)	33

In the course of the season Assistant Greenwell inked and forwarded to the office three other sheets of topography and one sheet of hydrography.

Triangulation and topography of San Luis Obispo Bay.—Sub-Assistant L. A. Sengteller, after inking his topographical sheets of last year, sent tracings to the office, and forwarded, also, the computations resulting from the triangulation of the season. He then made arrangements for resuming field operations.

In January his party was organized at San Luis Obispo Bay. After measuring a line of nine hundred and fifty-five metres with the subsidiary base apparatus a tertiary triangulation was

extended for the topographical work. Mr. Sengteller also observed a preliminary azimuth for his triangulation.

Part of the topography is carried over a very difficult and wild country, forming the southern flank of Mount Buchon, the base of which terminates in abrupt rocky cliffs bordering the sea. The mountain is covered with dense chaparral, through which it was necessary to open trails. The survey embraces the shores and approaches of the bay, the outlying rocks, and the eastern landing. A tracing of the uninked sheet was forwarded to the office with the records of the triangulation. The following are statistics of the work:

Signals erected	10
Stations occupied	9
Angles measured	53
Stations determined	10
Observations	1,197
Miles of shore-line traced	6¾
Miles of streams surveyed	4½
Miles of roads surveyed	5
Area, (square miles)	5

In April Mr. Sengteller transferred his party to Point Arena.

Triangulation and topography of San Simeon Bay.—Assistant Cleveland Rockwell completed, in the course of the winter of 1870, the office-work on his three sheets of the Columbia River topography. In January he transferred his party to San Simeon Bay, measured a line of eight hundred and sixteen metres with the subsidiary-base apparatus, and extended a tertiary triangulation therefrom for his topography, which now includes the bay of San Simeon and the shore to the westward. The country is a moderately elevated series of rolling hills, mostly covered with grass, and offering facilities for the work. The statistics are annexed:

Signals erected	9
Stations occupied	9
Angles measured	47
Observations	969
Miles of shore-line traced	8
Miles of roads surveyed	13¼
Area, (square miles)	10

The duplicate of the triangulation record has been received at the office.

Assistant Rockwell was aided by Mr. George H. Wilson. At the end of March he transferred his party to the northern coast for service, which will be mentioned under the head of Section XI.

Falmouth Shoal or Reed Rocks.—In July last, after closing work at Magdalena, in Lower California, and before the return of the schooner Marcy to San Francisco, Sub-Assistant Gershom Bradford made prolonged search in the Pacific about eight hundred miles west of the Golden Gate, in the vicinity of a reported danger. The authorities are positive in regard to the existence of the rock or shoal, but discordant, as might be expected, in reference to the geographical position. The assigned latitudes of the place range as much as a quarter of a degree.

During this examination the vessel ran over one thousand miles. Fifty-nine positions were determined in the vicinity. Soundings were frequently tried, but no bottom was found even with the deep-sea line of 1,850 fathoms. The weather was favorable.

In the opinion of Assistant Davidson, who collated the authorities and conferred personally with the navigators who report the danger, the rocks are probably isolated points coming from a great depth. The deep blue water of the vicinity, smooth when the weather is fair, and the absence of sea-gulls and seals, that harbor in the vicinity of certain shoals, make the position difficult to find.

Another examination will be conducted with a view to the hydrographic development of the vicinity in which the reported danger exists.

(See Sketch No. 34.)

Survey of Table Mountain and of wharf-lines at Oakland, Cal.—Assistant A. F. Rodgers passed

the winter of 1870 at San Francisco, in computing and duplicating his triangulation records of the previous season. He also inked the plane-table sheets of last year, and made a comparative map to show changes at Eel River entrance. Tracings of his survey of the vicinity of Trinidad Head were made for the Light-House Board.

After tracing on the proper topographical sheet the wharves and improvements recently made at Oakland Point, Mr. Rodgers took up the survey of Table Mountain, the well-known headland north of the entrance to San Francisco Bay. The triangulation made as a basis for the topography connects with that of the vicinity of San Francisco. Before completing the survey of the landmark, the time arrived for resuming field-work near Cape Mendocino, to which reference will be made under a separate head.

Assistant Rodgers was aided in the work near San Francisco by Mr. E. F. Dickins. The detailed survey of Table Mountain will be completed after the return of the party from the upper part of the section.

Blossom Rock, San Francisco Bay, Cal.—After the close of operations by the United States engineers for the removal of Blossom Rock, a hydrographic survey was made under the direction of Assistant George Davidson. Great care was exercised in the determination of the depth, and in fixing the position of each sounding, as well as in the reduction of the soundings to the *datum* of mean low water. This detailed survey was made by Sub-Assistant G. Farquhar. On account of the strong and irregular currents, the time for sounding was limited to one hour at each tide on fair days, and casts were recorded only when made in smooth water. An aggregate of about one thousand soundings were plotted from over two thousand angular measurements with the theodolite. The resulting chart, on a large scale, is now at the office. As shown by the soundings, the operations of the engineers have increased the depth of water on Blossom Rock to twenty-four feet.

Sub-Assistant Farquhar has made in general the projections needed for the hydrographic work on the western coast, though suffering much during the season from disease incurred in the prosecution of previous duty afloat. He is now in service in the party of Assistant Davidson.

Rocks in Mission Bay, (San Francisco Harbor.)—While Assistant Davidson was at San Francisco, a small rock was reported as having been found in Mission Bay to the southward of the city. Going at once to the vicinity with his aid, Mr. S. R. Throckmorton, two small heads of rock were found, having only twelve and a half feet on them at mean low water, the depth around the rocks being five and six fathoms. Mr. Davidson, after determining the position, published a notice containing the ranges for avoiding the rocks. Subsequently the Light-House Board placed a buoy on this danger to the navigation of Mission Bay.

San Francisco Bay and approaches.—Some progress has been made at intervals by the hydrographic party of Sub-Assistant Gershom Bradford, with the schooner *Marcy*, in the minute hydrographic survey of the Golden Gate and its approaches, the object being to determine what changes are going on, and to establish a basis for future comparisons. The work has been subject to the requirements of the service in other quarters; hence it was discontinued when call was made for the hydrographic development at Magdalena Bay, which was mentioned in a preceding notice. The party resumed work near the Golden Gate in October, after completing the survey of the Orford Reef, of which mention will be made under a separate head. Observations made in regard to the currents have already afforded matter of great interest. Nearly three thousand soundings were recorded by the party in the vicinity of the entrance to San Francisco Bay.

Triangulation and topography north of Point Arena, Cal.—As soon as the season would permit, Sub-Assistant L. A. Sengteller transferred his party to Cuffey's Cove, deferring until winter the continuance of work near San Luis Obispo, of which mention has already been made. Having measured a base-line of 1,075 meters at Navarro Ridge, north of Point Arena, the triangulation was brought up to that limit and connected with the base. Mr. Sengteller, before returning the apparatus to San Francisco, also measured the base which had been laid out at the commencement of the triangulation at Point Arena. This work is now connected with the astronomical station occupied by Assistant Davidson in 1852.

Bad weather prevailed in this section during the year. The topographical survey, however, was extended to Mendocino Bay. The following synopsis comprises the statistics of field-work:

Signals erected	33
Stations occupied	30
Angles measured	293
Number of observations	5,810
Miles of shore-line surveyed	19
Miles of roads surveyed	21
Area, (square miles)	8¼

The smoke of great fires in the forest north of Point Arena conjoined with dense fogs and strong winds to retard the progress of this party. In the course of the season Mr. Sengteller completed the records of his previous work, and transmitted results to the office. He is now making arrangements to resume field-duty on the coast south of Monterey.

Triangulation and topography south of Cape Mendocino, Cal.—When the season opened for field-work north of San Francisco, Assistant A. F. Rodgers resumed his survey of the coast south of Cape Mendocino. His party is yet on the coast near Shelter Cove, the triangulation having been extended southward from the cape. The region is difficult of access, rugged mountains coming down quite to the coast-line. Ten of the stations used for the triangulation are at elevations of more than two thousand feet, and in order to reach them trails were cut through the chaparral. As the party remained at work after the setting in of the wet season, the following synopsis represents only part of the results of the year:

Stations occupied	59
Positions determined	75
Number of observations	1,000
Area, (square miles)	80

While Assistant Rodgers carried forward the triangulation, his aid, Mr. E. F. Dickins, mapped the coast southward of Cape Mendocino. A few miles south of Shelter Cove the topography will be taken up with two plane-tables. Great energy has been manifested in the prosecution of this work under many natural difficulties. Some of the signals were destroyed by forest-fires, the smoke from which also retarded operations. At this time the survey in charge of Assistant Rodgers comprises three sheets of detailed topography below Cape Mendocino, and four others on which shore-line has been traced to a point several miles south of Shelter Cove, where the party is yet at work.

Views drawn by Assistant Davidson were received at the office in January, representing the appearance from sea of Cape Mendocino and Cape Fortunas. The drawings were accompanied by special views of the rocks adjacent to the two capes. These, with others furnished by Mr. Davidson, will be engraved for the general charts of the coast.

Sunken rocks south of Punta Gorda, Cal.—While prosecuting the coast topography south of Punta Gorda, Assistant Rodgers noticed a very heavy, but not frequent, break in the water about one mile off shore, caused evidently by a sunken rock. The tide was low, and the water, at the time, was smooth, but a heavy swell was coming in from the eastward. Mr. Rodgers determined the position of the sunken rock. It is generally known that such dangers exist on parts of the coast not yet reached by the hydrographic operations. Where, as in the present case, the danger lies near the coast line, the practice of steamers in making their courses quite near to the shore cannot be justified. In ordinary weather, during which the sea in the vicinity of Punta Gorda is marked by "white-caps," it is probable that this danger would be overlooked by passing vessels.

Triangulation and topography of the coast north of the False Klamath, Cal.—Mention has been made, under another head, of the occupation of the party of Sub-Assistant A. W. Chase during the winter. At the opening of the season he resumed work near Crescent City, and extended the triangulation southward as far as the False Klamath. This part of the coast of California is high and rough. The ocean-front of the mountains is about twelve hundred feet high at the distance of a mile from the water-line, and, being forest-clad, the region presents many obstacles to the progress of the triangulation.

After completing the angular measurements, Mr. Chase extended the plane-table survey so as to

include ten miles of the coast north of the False Klamath. His party was then transferred to a site of work which will be referred to in the next section.

In his general report Assistant Davidson makes favorable mention of the expedients used for carrying on the work below Crescent City, after having personally examined that stretch of coast with reference to the means proper for its development.

A synopsis of the statistics of work north of the False Klamath is subjoined:

Signals erected	22
Stations occupied	20
Angles measured	79
Number of observations	832
Miles of shore-line surveyed	10½
Area of topography, (square miles)	8½

The outlying rocks along the coast were carefully marked in position and appear on the plane-table sheet.

Rock in Crescent City Bay, Cal.—In the course of the season in this section Sub-Assistant Chase discovered and surveyed a dangerous ledge lying directly in the way of steamers entering Crescent City Harbor from the southward. In ordinary winds from the northwest, the water does not break on the ledge, but doubtless does in heavy southwest weather. The rock is several hundred yards in extent, and is not well marked by kelp. The depth on it, as determined by 165 casts of the lead, is 4 fathoms at mean low water, with 13 to 15 fathoms all around the ledge. This danger, which I have named "Chase Ledge," is less than two miles from Crescent City light-house. A description has been published in the usual form as a notice to mariners.

Azimuth at Eureka and Crescent City, Cal.—In the course of the season Assistant George Davidson occupied a station of the triangulation near Crescent City, and observed for azimuth with the twelve-inch theodolite No. 37. The record includes 54 observations on the sun and Polaris. A second station of the triangulation being used as an azimuth-mark, the connection is direct and complete. For this work the transit instrument was put in the meridian, and eight transits were recorded for time, in addition to twelve double altitudes of the sun. Mr. Davidson made 108 measures of thread intervals with the micrometer. The transcripts of the work have been received at the office. Messrs. S. R. Throckmorton and H. I. Willey aided in the observations.

The station Eureka, in Humboldt Bay, was occupied by Mr. Davidson for azimuth, with theodolite No. 37, by means of which he recorded 42 observations on Polaris. The connection was made direct, as at Crescent City, by using one of the stations of the triangulation as an azimuth-mark. With the transit instrument in the meridian, 25 passages of 18 stars were observed on 2 nights. The record in duplicate is now on file in the office.

Observations for the value of the level scale were made by 24 repetitions with the vertical circle of theodolite No. 57.

Assistant Davidson has computed a table of the azimuths and apparent altitudes of Polaris for varying latitudes and hour-angles, to assist in placing the instrument in the plane of the meridian. As a result, the time occupied in adjusting the new meridian instrument is less than half an hour.

At the astronomical station near Eureka, observations were made to determine the magnetic declination.

Before leaving this section, Mr. Davidson made a careful view from sea, showing Orford Reef and the neighboring coast-features. The drawing is now on file in the office.

Aids to navigation.—In furtherance of the general interests of navigation, several communications from the Assistants in this section and Section XI have been transmitted to the Light-House Board within the year. Assistant Davidson reports that in heavy northwest weather a good lee and safe anchorage can be had at Dume Cove, two miles east of Point Dume. At present, vessels under stress of weather usually run for San Pedro. Assistant Greenwell several years ago called attention to the shelter afforded at Dume Cove.

In other reports Mr. Davidson recommends the placing of lights on Point Hueneme and Anacapa Island, and buoys for the bar, entrance and harbor of San Francisco. He specifies also

the dangers to navigation off Point Año Nuevo. Special attention was given in the course of the year to exactness in the assigned geographical positions of the lights. After verifying the record, Mr. Davidson furnished a complete list for the use of the Light-House Board.

Assistant Rodgers recommends the erection of a light at Shelter Cove, and, in specifying the dangers between that anchorage and Cape Mendocino, calls attention to the risk incurred by steamers in passing northward too near to the shore.

At Crescent City Bay, buoys to serve as aids in navigation are recommended in the report of Assistant Davidson.

Tidal observations.—The stations on the Pacific coast have remained under the very efficient supervision of Bvt. Col. G. H. Mendell, U. S. A., who has ably met every requisition from the office in Washington. The observations at these stations are generally excellent, and the observers experienced and attentive. Mr. William Knapp has remained in charge of the self-registering gauge at San Diego, and Mr. F. P. Thompson in charge of the one at Fort Point. Each observer has also kept up a good series of meteorological observations, and tabulated the readings of high and low waters taken from the tide-rolls by using the improved graduated glass scales furnished from the office for this purpose.

SECTION XI.

COAST OF OREGON AND OF WASHINGTON TERRITORY, INCLUDING THE INTERIOR BAYS, PORTS, AND RIVERS. (SKETCHES Nos. 11 and 12.)

Triangulation and topography north of Chetko River entrance, coast of Oregon.—After completing a plane-table sheet of the upper part of the coast of California, Sub-Assistant A. W. Chase moved his camp and party to the coast of Oregon, and took up the triangulation north of Chetko River, where he had discontinued work last year. From that limit he extended the triangulation northward and westward toward Cape San Sebastian. Land operations on this part of the coast are almost impracticable. There being no roads, Mr. Chase was able to occupy his stations only by cutting trails through chaparral from one point to another. Two of the stations are on large outlying rocks, one of which was occupied with the theodolite. About eight miles of the coast are represented on plane-table sheet. The general statistics of the work are:

Signals erected	20
Stations occupied	19
Angles measured	106
Number of observations	1,272
Miles of shore-line surveyed	11
Area of topography, (square miles)	8

This field-work was closed late in October. Progress was much hindered by strong winds, and during August and September by smoke from the burning forests to the northward of Cape San Sebastian.

Sub-Assistant Chase is now engaged with a party at San Pedro Bay.

Hydrography of Orford Reef, coast of Oregon.—This work was taken up by Sub-Assistant Gershom Bradford, after the return of his party in the schooner *Marcy* from the vicinity of Falmouth Shoal, which was the subject of a preceding notice. Unfavorable weather interrupted the operations generally on the coast of Oregon, but Mr. Bradford succeeded in sounding out the ship-channel between the main shore and the reef, and partly developed the reef and islets. On the plotted chart the limits of safe navigation are well marked, and also the approaches from the southward. The following is an abstract of statistics:

Signals erected	7
Miles run in sounding	140
Angles of position	1,040
Number of soundings	2,533

The party returned to San Francisco late in October, and before laying up the vessel made additional soundings in the vicinity of the Golden Gate, as already stated.

Orford Reef and the coast-features adjacent to it are well represented by a drawing, which was furnished in January last, by Assistant Davidson.

Triangulation and topography of Columbia River, Oregon.—Assistant Cleveland Rockwell resumed the survey of the Columbia River in May. Many difficulties were encountered in advancing the triangulation. The shores are covered with heavy timber, through which at high points lines of sight were required to bring stations into view that otherwise would be hid by the dense growth of timber on the islands in the river. By well-conditioned triangles, however, Mr. Rockwell succeeded in extending the preliminary work to Westport, which by the river course is about twelve miles above Cathlamet Point.

The topography was taken up at Three Tree Point, on a sheet projected by Mr. Rockwell to take in the river shores as far as the lower end of Puget Island. His plane-table survey includes both banks of the Columbia, which, between the limits stated, is nearly three miles wide. All the islands between Cathlamet Point and Puget Island are represented on the sheet. The river banks are shown as being high, abrupt, and broken; densely timbered and covered with thick underbrush. In the site of work occupied by the party this year there is no river valley; the shores have a steep pitch at the water-line. The basin of the Columbia is from two to five miles wide, and the area between the shores is filled with an intricacy of low marshy islands, which are covered with spruce, cotton-wood, and alder. The islands are overflowed by freshets and by high tides.

While carrying on the triangulation, Assistant Rockwell determined the positions of notable mountain peaks and ridges that were in view from the stations occupied for his work. A synopsis of the statistics is subjoined:

Signals erected	13
Stations occupied	13
Angles measured	39
Number of observations	1,461
Miles of shore-line surveyed	71
Area of topography, (square miles)	13

The operations of this party, as of the parties generally on the western coast, were retarded by dense smoke from the burning woods of Oregon and Washington Territory.

Mr. G. H. Wilson aided in the field-work on the shores of the Columbia.

Assistant Rockwell is now in service near San Simeon Bay, in Section X.

Triangulation and topography of Shoalwater Bay, Wash.—For the service in Shoalwater Bay, Assistant Davidson provided a suitable outfit of tents and instruments, and at his suggestion the work was intrusted to Sub-Assistant J. J. Gilbert. Field operations were commenced in the spring with a view to connect this survey with that of the Columbia River, and to join it at the north with the survey of Gray's Harbor.

Shoalwater Bay, as the name implies, is filled with great shoals; the channels are tortuous, and the low shores are covered with timber and underbrush. Notwithstanding the disadvantages for progress, Mr. Gilbert established a good triangulation, and determined also a series of points along the low wooded peninsula which separates the body of the bay from the ocean. Among the points is included the light-house on Cape Shoalwater.

Sub-Assistant Gilbert surveyed the shore-line and mapped the topography within the limits of his triangulation. The following are statistics of the field-work:

Signals erected	45
Stations occupied	29
Angles measured	279
Number of observations	1,980
Miles of shore-line traced	73
Area, (square miles)	23

At the entrance of the bay extensive changes have taken place within recent years. Where a large island existed in 1854, the water is now ten feet deep. Leadbetter Point and Cape Shoalwater have increased rapidly. Both are marked by loose sand-dunes that change in form and position with every wind. Mr. Gilbert traced the shore-lines of Shoalwater Bay separately at high and at low water. His party is yet at work, and will continue in the field as long as the season will permit.

Longitude of Seattle, W. T.—While Assistant George Davidson was engaged in special examinations at the United States branch mint in San Francisco, his party was at Seattle in charge of the aid, Mr. S. R. Throckmorton, jr., to occupy an astronomical station there for the determination of longitude by telegraph from San Francisco, where Mr. Davidson directed operations from the station in Washington Square. By the usual liberality of the Western Union Telegraph Company, this work was successfully accomplished, although the condition of the line was much disturbed by great fires in the forests of Oregon and Washington Territory, which sometimes destroyed the connections. At the Washington Square station, Mr. Davidson observed 602 transits of 81 stars on 38 nights, and transmitted clock-signals on 12 nights. After the return of Mr. Throckmorton, observations were made, as customary, for personal equation. These included 92 transits of 54 stars on 4 nights. This longitude-work, in 4 volumes and 61 chronograph sheets, has been duplicated. No aid being available at San Francisco, Mr. Davidson, under the necessity, conducted the mint comparisons while the operations for longitude were in progress.

Before leaving Seattle, Mr. Throckmorton, aided by Mr. H. I. Willey, determined the magnetic declination, dip, and horizontal intensity at the astronomical station.

Triangulation and topography of the Strait of Fuca, W. T.—Assistant James S. Lawson was engaged during the winter of 1870 in computations resulting from his field-work of the previous season, and in inking plane-table sheets. Eight in all were forwarded to the office, with twenty-five records containing the observations and results. When the season opened for field-work, his party was organized and operations resumed near Nisqually. A base of 900 meters was measured in May on the plains, and the line was connected by angular measurements with the triangulation made last year between Puget Sound and Muck Prairie. On the completion of this work the party, in the brig *Fauntleroy*, sailed for the Strait of Fuca. Arrangements were made without delay for connecting the triangulation of Admiralty Inlet with the stations which had been occupied on the shores of Rosario Strait and the Canal de Haro, but the smoky atmosphere made the continuance of the work impracticable at that time.

Sub-Assistant Eugene Ellicott joined the party in June, and was assigned to service with the plane-table on the west side of Whidbey Island. For the extension of his work, points were determined by Assistant Lawson from Deception Pass to the southward, the stations having been previously selected. Stations were also occupied to embrace the eastern end of the Strait of Fuca in the general triangulation, and, by a series of smaller triangles, the upper part of Admiralty Inlet and Kilisut Harbor were included.

The topography was commenced at Deception Pass. After tracing the shore-lines the survey was extended northward to Sares Head, on Fidalgo Island. Southward of the pass the plane-table work was continued, and finally joined with previous work near the light-house on Admiralty Head. The western part of Penn's Cove, a harbor of Whidbey Island, is included in the survey made by Sub-Assistant Ellicott. He completed also the topography of Kilisut Harbor, which had been commenced by Mr. Lawson, who found a good depth and safe anchorage while engaged in the survey. The aggregate statistics of field-work are as follows:

Signals erected	18
Stations occupied	32
Angles measured	178
Number of observations	5,936
Miles of shore-line surveyed	71
Miles of road surveyed	22
Area of topography, (square miles)	40

Hydrography of Partridge Bank, Lawson Reef, and Belle Rock.—Heavy westerly winds prevailed in July and August, while Assistant Lawson was engaged in the development of Partridge Bank, and these, conjoined with the irregular currents in the vicinty, made the prosecution of soundings a work of great difficulty. The survey, however, was successfully made. It shows that between the ten-fathom curves the bank is three miles long and a mile and a half wide, and that the eastern end is within four miles of the shore of Whidbey Island. The soundings have developed a very dangerous rocky ledge, on which the depth of the lowest tide is only fourteen feet. By the

very strong and irregular currents, the kelp, which would otherwise be a warning, is sometimes torn off, or run under, so that vessels on the lookout cannot make sure of the position to be avoided. On the recommendation of Assistant Lawson, a buoy was placed on the bank by direction of the Light-House Board. Lawson Reef was discovered by the party in the brig *Fauntleroy* last year. Mr. Lawson made the hydrographic development in the steam-launch *Lively*, in the course of the present season, while conducting other operations in the field, and under circumstances of weather very unfavorable. The least depth found was twenty feet. Being compelled by stress of weather to seek a harbor, the party found good anchorage at the south end of Burrow's Bay, in a position which heretofore has had no repute as a harbor.

Assistant Lawson noticed, while sounding in the vicinity of the reef, that the tides were very irregular, there being for several days only one high and one low water each day. In one case the ebb continued to run for a period of fourteen hours.

Belle Rock was sounded and determined in position. The least depth found by Mr. Lawson was eighty fathoms. The following is a synopsis of the statistics:

Miles run in sounding	209
Angles measured	1,594
Number of soundings	3,739

Mr. F. A. Lawson served as aid in the hydrographic party, and also in the field operations.

Assistants Davidson and Lawson united in the recommendation for placing buoys on Itsami Shoal and Toliva Shoal, as aids in the navigation of Puget Sound.

Tidal observations.—The station at Astoria, with the others on the western coast, has remained under the able supervision of G. H. Mendell, major engineers, brevet colonel, United States Army. The self-registering gauge is attended by Mr. L. Wilson, who has for many years kept up an excellent series of both tidal and meteorological observations at this station. He also tabulates the readings of high and low waters, taken from the tide-rolls, with a graduated glass scale.

SECTION XII.

PACIFIC COAST, ALASKA TERRITORY.

A party in charge of Assistant W. H. Dall is now in the vicinity of the Aleutian Islands, with the schooner *Humboldt*. The equipment for service included means for making hydrographic surveys, recording tidal observations, and for increasing generally our information in regard to the coast of Alaska.

Before leaving San Francisco in August, Mr. Dall conferred freely with Assistant Davidson, who had collected many particulars of interest and importance in his reconnaissances of the coast of Alaska in 1867, and during his visit to the Yukon River for observing the solar eclipse of 1869.

No returns have been received as yet from the party of Mr. Dall, but report of the safe arrival of the *Humboldt* at Kodiak is hoped for daily. A self-registering tide-gauge, carefully adjusted at the Coast Survey Office, was sent in the vessel, to be set up at Ilioulionk, near the eastern end of the Aleutians. At Saint Paul's Island, about two hundred and fifty miles northwest from the proposed tidal station, my friend, Capt. Charles Bryant, recorded meteorological observations continuously for a period of eight months, beginning with November, 1870. By his kindness I am enabled to include a copy of the record, which will be found in Appendix No. 7.

COAST SURVEY OFFICE.

The operations of the Coast Survey Office have been conducted, as heretofore, by Assistant J. E. Hilgard.

The inconvenient and insecure condition of the buildings occupied by the office had long occasioned apprehension as to the safety of the valuable records accumulated during many years, besides involving much loss of time, from the fact that the houses occupied were scattered at different points within a square of the city. In order to correct these disadvantages, an arrangement was entered into with Messrs. T. and A. T. Richards for the construction of a suitable building, situated between the Capitol and the former site of the office, which was ready for occupation

on the 1st of January, 1871. By the 1st of March all the different departments of the office had been moved into it. Besides the security of the records by the fire-proof character of the building, great advantage has been experienced from having all the operations of the office under the same roof.

The following statement gives a succinct account of the operations of the office during the past year, which have fully kept pace with the advance of operations in the field.

Hydrographic division.—The planning and verifying of the work of the sounding parties is under the immediate direction of Capt. C. P. Patterson, inspector of hydrography, who also has charge of the construction, repairs, and disposition of the vessels belonging to the Coast Survey service. The office-work under his direction has been performed by Mr. E. Willenbücher, as principal hydrographic draughtsman, who has plotted sixteen original hydrographic sheets, in addition to making the verification of sheets drawn by others, besides drawing numerous projections, reductions, tracings, and performing other miscellaneous work relating to lights, buoys, and sailing-directions. Mr. J. Sprandel, as assistant draughtsman, has equally performed a creditable amount of work.

Computing division.—Assistant Charles A. Schott continued in charge of this division during the past year. The force of permanent computers, consisting of Messrs. T. W. Werner, James Main, G. Rumpf, and E. Courtenay, has remained the same, in addition to whom the assistance of Messrs. F. Hudson and R. Keith was occasionally used, in order to keep up with the rapidly-increasing amount of field-work, both in triangulation and astronomical observations.

Assistant Schott served as a member of the party of the Superintendent for observing the solar eclipse of December 22, 1870. His services as an observer at Catania, Italy, are noticed in Appendix No. 16 to the report of 1870.

Magnetic observations for declination, dip, and intensity were made by him in June, at Washington, in continuation of the regular series observed by him. Among the great number of reports submitted by him as chief of the computing division, the following may be specially mentioned: On the results from pendulum observations, made at the Coast Survey Office; on the present state of the question of pendulum observations in connection with geodetic surveys; on the connection of the primary base-lines of Kent Island, Md., and Craney Island, Va., and on the degree of accuracy of the intervening triangulation; a new investigation of the secular changes in the magnetic declination, dip, and intensity of the magnetic force at Washington, D. C.; results of eclipse observations at Catania, and on the result of the micrometer measures of the negatives of the eclipse of the sun, taken at Springfield, Ill., August, 1869. He also investigated two recent hypsometrical formulæ, one relating to trigonometrical, the other to barometrical measures, besides furnishing numerous reports on the routine work of the division, and promptly meeting all calls upon him for data needed in other branches of the survey.

Tidal division.—The duties of this division, consisting of the reduction of the tidal and meteorological observations taken at the several established stations on the Atlantic and Pacific coasts, correspondence with observers, inspection of new apparatus, and supervision of repairs to those in service, have been directed by Mr. R. S. Avery, assisted by Mr. A. Gottheil, Mr. J. Downes, and Miss M. Thomas. The tables of predictions of tides for the principal ports for the year 1872 have been computed and published. Various improvements have been introduced in the method of prediction by the comparison of predictions with observations in each succeeding year. All information for use in office and field-work, and in reply to applications for information relative to tides, has been promptly furnished. The particulars relating to the several permanent tidal stations have been mentioned under the heads of the respective sections in which they are situated.

Drawing division.—The operations of this branch of the office have been conducted under the immediate direction of the assistant in charge, Mr. W. T. Bright assisting in charge of the details. The following draughtsmen, comprising the permanent force of the division, have executed the drawings for engraved charts: Mr. A. Lindenkohl, chief draughtsman, and Messrs. H. Lindenkohl, L. Karcher, F. Smith, and F. Fairfax. Mr. W. Fairfax made traced copies of maps as they were required for office and field purposes. Mr. W. McMurtrie was engaged during the year in taking views of headlands and approaches to harbors. A list of the manuscript maps and charts furnished to other branches of the public service and to private persons, the cost thereof being

paid by the latter, is given in Appendix No. 2. A tabular statement of the charts completed or in progress during the year, with the names of the draughtsmen engaged upon them, is shown by Appendix No. 3.

Engraving division.—This division has remained under the charge of Assistant E. Hergesheimer, whose executive ability, no less than his professional knowledge and cultivated taste, has done much to advance the efficiency of the work under his charge and to improve the perspicuity of the charts, while maintaining their artistic character. Mr. Hergesheimer reports the completion of twenty-three charts, engraved on copper, the commencement of work on seven new plates, and the advancement of the engraving upon twenty-eight, some of them fully up to the field-work.

During the year the custody of the "altos," or electrotype relief-moulds, has been transferred from the electrotype to the engraving division. They have all been examined and assorted. Such as had served a temporary purpose in the construction of new "bassos" have been condemned, the remainder having been registered and stored in convenient cases in the basement of the office.

The engraved and electrotype plates have heretofore been stored together in the order of their accumulation. The removal to the new office has afforded an opportunity to make a careful examination of the same and a separation of the standard and printing-plates, with a selection of the most important of the former for storage by themselves. Some standards that have become obsolete will be boxed for preservation. The printing-plates occupy a room separate from the standards, and convenient to the printing-office.

The force of engravers has remained the same as last year: Messrs. J. Enthoffer, H. C. Evans, A. Sengteller, and A. M. Maedel, topographical engravers; John Knight, E. A. Maedel, and A. Petersen, letter engravers; H. S. Barnard, J. C. Kondrup, R. F. Bartle, W. A. Thompson, H. M. Knight, J. G. Thompson, F. W. Benner, E. H. Sipe, and W. H. Davis, miscellaneous engravers. During part of the year Mr. F. Courtenay has engraved lettering and Mr. George McCoy views, both on contract. Mr. E. Molkow has continued the use of the pantograph, and Mr. George A. Morrison has performed the clerical duties of the division.

A tabular statement of the charts worked upon during the year, with the names of engravers engaged upon them, is given in Appendix No. 4. The system and styles of lettering used on the Coast Survey charts are exhibited by Sketch No. 31.

Electrotyping and photographing.—The operations of this division of the office during the year, continued by Mr. George Mathiot, with Mr. F. Ober as assistant, embrace the production of thirty-two electrotypes of the engraved plates of the survey, the reduction of sixteen topographical field-sheets by photography for engraving on the scale of the coast chart series, furnishing the requisite positives on glass for the direct use of the engraver, and reduced prints on paper for the elaboration of details by the draughtsman.

Division of charts and instruments.—Mr. John T. Hoover has directed, with his accustomed zeal and energy, the duties of this division, which comprise the safe-keeping of records and maps, printing and distribution of charts, and work of the mechanician's and carpenter's shops, including the dispatch of instruments for field-parties. The registering and filing the original maps and charts, and records of observations made in the field, has continued with Mr. A. Zumbrock.

Within the year 8,931 copies of charts and sketches have been printed from the copper-plate press, worked by Mr. T. V. Durham.

The preparation of backed sheets of drawing-paper for field and office use, and the miscellaneous duties pertaining to the bindery and folding-room, have been very satisfactorily performed by Mr. H. Nissen.

Mr. T. McDonnell has remained in charge of the map room. There have been issued during the year an aggregate of 10,283 copies of charts, and a distribution of 1,970 copies of the annual reports of various years has been made.

The work of repairing and reconstructing instruments was done under the supervision of Mr. John Clark, by J. Foller, W. Jacobi, C. F. Wurdemann, and apprentice, E. Eshleman.

The wood-work of instruments, their packing for transportation, and all carpentry-work required in and about the office, was done by Mr. A. Yeatman, assisted by Mr. F. E. Lackey.

The duties of chief clerk of the office, the charge of the general correspondence, and the office

accounts have, as heretofore, been performed by Mr. V. E. King, assisted, since April 1, by Mr. F. W. Clancy. Mr. C. A. Hoover acted as writer in the hydrographic division during the entire year Mr. R. L. Hawkins has discharged the duties of principal accountant and book-keeper in the office. of the general disbursing agent of the Coast Survey, Samuel Hein, esq., and the clerical duties of that office have been performed by Mr. W. A. Herbert, assisted by Mr. H. Hein as writer.

CONCLUSION.

Previous to the completion of the edifice now occupied by the office, the assistant in charge, J. E. Hilgard, esq., had, in the plan of the building, marked out the quarters to be allotted to the several divisions. After the removal I made a careful inspection of each of the office divisions, and was gratified by the good judgment shown in their new arrangement. While bringing together, as was desirable, the branches of work most nearly related, it was borne in mind that they include many members with special talent and decided individuality. Hence the adjustment with reference to unity and effectiveness was not an easy task, but it has been accomplished to my entire satisfaction. My thanks are due also for the earnest co-operation of Mr. Hilgard in conducting the work of the present year.

Samuel Hein, esq., continues in charge of the finances of the survey, and it is known at the Department that his accounts are presented invariably in lucid form. As disbursing agent, his scrupulous regard to economy and promptness in stating the means available for service at any period of the season have been indispensable adjuncts in the proper control of the observations of the survey. The experience of Assistant W. W. Cooper in official details has also furthered, as heretofore, the discharge of the administrative duties which devolve on the Superintendent.

It is just to add, in conclusion, that the cordial assistance of able officers has liberated me from much labor in the routine of the service. Time is thus afforded for considering suggestions that have bearing upon the general interests of the work and its relations, as well to the requirements of our commerce, navigation, and national reputation, as to the demands of science. In an age so practical as the present these several objects may be regarded as commensurate.

Respectfully submitted,

BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

Hon. GEORGE S. BOUTWELL,
Secretary of the Treasury.

APPENDIX.

APPENDIX No. 1.

***Distribution of surveying parties upon the Atlantic, Gulf, and Pacific coasts of the United States during the surveying season of* 1870–'71.**

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I.				
Atlantic coast of Maine, **New Hampshire**, **Massachusetts**, and **Rhode Island**, including **seaports**, **bays**, and rivers.	No. 1	Hydrography	Horace Anderson, sub-assistant; C. H. Van Orden, aid; E. B. Pleasants, aid.	Soundings developing outer ledges in the approaches to Moose-a-bec Reach. Hydrography of Prospect Harbor, coast of Maine. (See also Section VII.)
	2	Topography and hydrography.	J. W. Donn, assistant; L. B. Wright, sub-assistant; F. C. Donn, aid.	Plane-table survey of the shores and adjacent islands, and hydrography of Somes' Sound, including Southwest Harbor, Mount Desert Island, Me. (See also Section III.)
	3	Topography	H. M. De Wees, sub-assistant	Topographical survey of Long and other islands bounding Seal Harbor, in the Fox Island group, at Penobscot entrance, coast of Maine. (See also Section VII.)
	4	Topography	W. H. Dennis, assistant; A. P. Barnard, aid.	Plane-table survey of Deer Isle Thoroughfare, and of adjacent islands and ledges on the east side of Isle au Haut Bay. (See also Section VI.)
	5	Topography	F. W. Dorr, assistant; C. T. Iardella, assistant.	Topography of the western shore of Penobscot Bay, above Camden, Me., including the shores of Belfast Bay, and nearly completing the intermediate details. (See also Section IV.)
	6	Topography	A. W. Longfellow, assistant; Joseph Hergesheimer, aid.	Completion of the detailed plane-table survey of Isleboro, in Penobscot Bay, Me., between Camden and Belfast Bay.
	7	Hydrography	F. P. Webber, assistant; D. B. Wainwright, S. N. Ogden, C. S. F. Hoffman, aids.	Hydrography of Penobscot Bay, east and west of Isleboro, Me., and from Camden northward to Belfast Bay, including Gilkey's Harbor. Development of Bradstreet's Rock, near the Fox Island Thoroughfare. Soundings in Seal Bay, completing hydrography in the vicinity of the Fox Islands. (See also Sections VI and VII.)
	8	Topography and hydrography.	C. H. Boyd, assistant; W. I. Vinal, sub-assistant.	Topography of the shores and soundings in the Androscoggin and Cathance Rivers, between Brunswick and Bowdoinham, Me. (See also Section VIII.)
	9	Hydrography	J. S. Bradford, assistant; E. H. King, aid.	Soundings in the approaches of Saco River, including Winter Harbor, Me. Hydrographic developments near Cape Porpoise and Stage Island, Me., and revision of the sailing-directions for harbors between Cape Small Point and Boston. (See also Section VIII.)
	10	Topography	Hull Adams, assistant; J. N. McClintock, aid.	Detailed plane-table survey of the shores of Saco River, Me., including Saco and Biddeford, and the coast northward to Spurwink River. (See also Section IV.)
	11	Triangulation	E. T. Quimby, acting assistant.....	Geodetic positions determined in the State of New Hampshire by secondary triangulation extended from the primary stations Monadnock and Unkonoonuc.
	12	Astronomical observations.	Prof. Joseph Winlock, director of Cambridge Observatory.	Exchanges of time-signals at Cambridge Observatory, Mass., for longitude determinations at Cleveland and Columbus, in Ohio, and at Falmouth, Oakland, and Shelbyville, in Kentucky. (See also Section VII.)

Distribution of surveying parties upon the Atlantic, Gulf, and Pacific coasts, &c.—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I—Continued....	No. 13	Topography and hydrography.	H. L. Whiting, assistant; H. Mitchell, assistant; H. L. Marindin, sub-assistant.	Shore-line survey and hydrography, with record of changes affecting the harbor facilities at Edgartown, Vineyard Haven, and Nantucket, Mass. (See also Section II.)
	14	Topography	A. M. Harrison, assistant; Bion Bradbury, jr., aid; W. H. Stearns, aid, (part of season.)	Topographical survey of the shores of Narragansett Bay completed, and details extended westward of Point Judith to the vicinity of Wakefield, R. I. Survey of wharf-lines for the harbor commissioners of Newport.
	....	Tidal observations.	J. G. Spaulding, H. Howland......	Series of observations continued with self-registering tide-gauges at North Haven, in Penobscot Bay, Me., and at Charlestown navy-yard, in Boston Harbor, Mass.
SECTION II. Atlantic coast and seaports of Connecticut, New York, New Jersey, Pennsylvania, and Delaware, including bays and rivers, and also Lake Champlain.	1	Triangulation.....	J. A. Sullivan, assistant; W. H. Stearns, aid.	Points determined from Point Judith westward to the vicinity of Charlestown, R. I., on the north shore of Long Island Sound. (See also Section VI.)
	2	Preservation of stations.	John Farley, assistant	Examination of station-marks formerly placed at Montauk Point, Shelter Island, Friar's Head, and Clarke Station, on Long Island; at Watch Hill, Champlin Hill, and Lantern Hill, on the coast of Rhode Island; at Nickerson, William's Hill, and Sugar Loaf Hill, on the coast of Connecticut, and at Yard Station, near Philadelphia.
	3	Triangulation.....	Edward Goodfellow, assistant....	Determination of points for the survey of New Haven Harbor. (See also Section VII.)
	4	Topography	R. M. Bache, assistant.............	Detailed topographical survey, including the Quinnipiac River and its branches, in the vicinity of New Haven, Conn.
	5	Reconnaissance..	Richard D. Cutts, assistant; B. A. Colonna, aid.	Reconnaissance and selection of sites for verification bases near the north end of Lake Champlain; signals erected for the lake triangulation between Kibbe's Point and the United States boundary.
	6	Triangulation.....	F. W. Perkins, sub-assistant	Triangulation of the eastern branch of Lake Champlain, from Kibbe's Point northward to Ball's Island, and measurement of verification bases. (See also Section IV.)
	7	Triangulation	G. A. Fairfield, assistant; F. W. Perkins, sub-assistant.	Triangulation of the eastern channel of Lake Champlain, from Ball's Island northward into Missisquoi Bay. (See also Section IV.)
	8	Triangulation.....	S. C. McCorkle, assistant; W. H. Stearns, aid, (part of season.)	Triangulation of the western channel of Lake Champlain, from Plattsburgh north to the United States boundary. (See also Sections I, VI, and VII.)
	9	Triangulation and topography.	Charles Hosmer, assistant; R. B. Palfrey, aid.	Shore-line survey of the eastern part of Lake Champlain, from Colchester Point northward to Butler's Island. (See also Section V.)
	10	Topography	J. N. McClintock, aid.............	Shores of the eastern branch of Lake Champlain traced from Butler's Island northward, to include McQuam Bay. (See also Sections I and V.)
	11	Topography	H. G. Ogden, sub-assistant; Andrew Braid, aid.	Western shores of Lake Champlain traced, and islands intervening, between Cumberland Head and the United States boundary, including the southern shore of Missisquoi Bay. (See also Sections VI and VII.)
	12	Hydrography	F. D. Granger, sub-assistant; F. W. Ring, aid; L. F. Chew, aid.	Soundings in Lake Champlain, from the upper end of Valcour Island southward to Ligonier Point and Shelburne Point. (See also Section IX.)

Distribution of surveying parties upon the Atlantic, Gulf, and Pacific coasts, &c.—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION II—Continued ..	No. 13	Physical hydrography.	H. Mitchell, assistant; H. L. Marindin, sub-assistant; F. H. North, aid.	Physical survey of Hudson River, N. Y.; soundings on the flats and in Buttermilk Channel to determine hydrographic alterations in New York Harbor. (See also Section I.)
	14	Hydrography	F. H. Gerdes, assistant; C. P. Dillaway, aid.	Shore-line survey and soundings in Newark Bay, including also the navigable parts of the Passaic and Hackensack Rivers. (See also Section VIII.)
	15	Triangulation	Richard D. Cutts, assistant; B. A. Colonna, aid.	Station occupied near Mount Holly, N. J., and other stations established for triangulation toward Barnegat light-house. Determination of altitudes at the primary stations in New Jersey.
	16	Topography	C. M. Bache, assistant; H. W. Bache, sub-assistant.	Plane-table survey of Great Bay, including the lower part of Mullica River and Little Egg Harbor, on the coast of New Jersey.
	17	Hydrography	W. W. Harding, sub-assistant, (part of season;) W. I. Vinal, sub-assistant, (part of season;) J. J. Evans, aid.	Soundings completed in Great Bay, N. J., and on the bar of Little Egg Harbor. Hydrography of Absecom Inlet, including parts of the adjacent waters. (See also Sections I, III, and IV.)
	18	Topography and hydrography.	A. Lindenkohl and Charles Junken, (part of season;) F. F. Nes, assistant; T. J. Lowry, aid.	Shore-line survey and soundings in Delaware River, from the Philadelphia Navy-yard to League Island, and survey of the Schuylkill River below Fairmount. (See also Section IV.
	....	Tidal observations.	R. T. Bassett	Series continued with self-registering tide-gauge at Governor's Island, in New York Harbor.
SECTION III. Atlantic coast and bays of Maryland and Virginia, including sea-ports and rivers.	1	Topography and hydrography.	J. W. Donn, assistant; L. B. Wright, sub-assistant.	Survey of the shores and development of the channels of the Broad Water, on the coast of Virginia. (See also Section I.)
	2	Astronomical observations.	A. T. Mosman, assistant; Edwin Smith, aid.	Latitude, azimuth, and the magnetic elements determined at Cove Point, Tangier Island, and Wolf Trap, primary stations on Chesapeake Bay. (See also Sections IV and VII.)
			Charles A. Schott, assistant	Magnetic observations on Capitol Hill, Washington, D. C. Pendulum adjusted for observing in the Arctic regions.
	3	Hydrography	W. W. Harding, sub-assistant	Shore-line survey and soundings in the branches of the Severn, Chester, and Choptank Rivers and in Chesapeake Bay, between Thomas' Point and Tally's Point. (See also Section II.)
	4	Triangulation	R. E. Halter, assistant; B. A. Colonna, aid.	Triangulation of James River, Va., from Jamestown Island upward to City Point. (See also Section VIII.)
	5	Geodetic operations.	C. O. Boutelle, assistant; F. Blake, jr., sub-assistant; A. H. Scott, aid; C. B. Boutelle, aid.	Geodetic observations at Clark's Mountain and Bull Run Mountain, Va., including determinations for latitude, azimuth, and the magnetic elements. (See also Section V.)
	....	Tidal observations.	W. J. Bodell	Series continued with the self-registering tide-gauge at Old Point Comfort, Va.
SECTION IV. Atlantic coast and sounds of North Carolina, including sea-ports and rivers.	1	Triangulation	G. A. Fairfield, assistant; F. W. Perkins, sub-assistant.	Stations occupied at Ocracoke Inlet, N. C., joining the Portsmouth base-line and extending the triangulation of Pamplico Sound. Triangulatino of Pungo River completed. (See also Section II.)
	2	Astronomical observations.	A. T. Mosman, assistant; Edwin Smith, aid.	Latitude, azimuth, and the magnetic elements determined near Portsmouth, N. C. (See also Sections III and VII.)
	3	Topography	F. W. Dorr, assistant; C. T. Iardella, assistant; A. P. Barnard, aid.	Plane-table survey of the shores and branches of Pamplico River, from Lee's Creek upward to the vicinity of Washington, N. C. (See also Section I.)

Distribution of surveying parties upon the Atlantic, Gulf, and Pacific coasts, &c.—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION IV—Continued..	No. 4	Hydrography	F. F. Nes, assistant; W. I. Vinal, sub-assistant.	Hydrographic survey of Pamlico River from its entrance upward to Cedar Grove, near Washington, N. C. (See also Sections I and II.)
	5	Hydrography	Acting master Robert Platt, U. S. N., assistant; J. B. Adamson, aid; C. L. Gardner, aid.	Soundings developing the character of the Hatteras Shoals, off the coast of North Carolina. (See also Section VI.)
	6	Topography	Hull Adams, assistant; Eugene Ellicott, sub-assistant.	Plane-table survey east and west of Swansborough, N. C., completing the topography of Bogue Sound and Inlet; and shore-line survey westward to New River Inlet (See also Sections I and XI.)
SECTION V.				
Atlantic coast and sea-water channels of South Carolina and Georgia, including sounds, harbors, and rivers.	1	Topography and hydrography.	Charles Hosmer, assistant; J. N. McClintock, aid.	Topographical survey and soundings, developing parts of the Combahee River and Bull River, S. C.; also, parts of the Chechessee, Colleton, and May Rivers; and the head-waters of Cooper River and Wright's River. (See also Sections I and II.)
	2	Reconnaissance.	C. O. Boutelle, assistant	Reconnaissance of the navigable rivers of South Carolina, with reference to methods of connecting their survey with that of the Sea Islands. (See also Section III.)
SECTION VI.				
Atlantic and Gulf coast of Florida peninsula, including the reefs and keys, and the sea-ports and rivers.	1	Topography	W. H. Dennis, assistant; Bion Bradbury, jr., aid.	Topographical survey of Nassau Sound, Fla., including the adjacent inside water-passages along the coast, and also parts of Talbot and Amelia Islands. (See also Section I.)
	2	Hydrography	F. P. Webber, assistant; Andrew Braid, D. B. Wainwright, and W. E. McClintock, aids.	Soundings to seaward of Nassau Bar and Amelia Island, Fla., and hydrography of Nassau Sound and of the inside water-channels between Saint Mary's River and Saint John's River. (See also Sections I and VII.)
	3	Triangulation.....	J. A. Sullivan, assistant; W. H. Stearns, aid.	Triangulation below Matanzas Inlet along the eastern coast of Florida to Braddock's Point. (See also Sections I and II.)
	4	Hydrography	Acting Master Robert Platt, U. S. N., assistant; J. B. Adamson, aid; C. L. Gardner, aid.	Hydrographic development of the "New Ground" near the quicksands, and soundings in the Gulf of Mexico near the Tortugas. (See also Section IV.)
	5	Hydrography	Lieut. Commander John A. Howell, U. S. N., assistant; Masters W. H. Jaques, E. S. Jacob, Richard Rush, and W. L. Field.	Hydrographic party organized for soundings in the Gulf of Mexico.
SECTION VII.				
Gulf coast and sounds of Western Florida, including the ports and rivers.	1	Hydrography	F. P. Webber, assistant; D. B. Wainwright, aid.	Soundings at Cedar Keys, on the Gulf coast of Florida, developing the channel from Sea-Horse Key to the railroad wharf. (See also Sections I and VI.)
	2	Hydrography	H. Anderson, sub-assistant; Arthur F. Pearl and G. W. Bissell, aids, (part of season;) R. B. Palfrey, aid, (part of season.)	Hydrography of Saint George's Sound, Fla., from Bulkhead Point eastward to Royal Bluff. (See also Section I.)
	3	Astronomical observations.	A. T. Mosman, assistant; Edwin Smith, aid.	Azimuth determined at Eagle Harbor, in Saint Joseph's Bay, Fla. (See also Sections III and IV.)
	4	Triangulation and topography.	S. C. McCorkle, assistant; H. M. De Wees, sub-assistant.	Triangulation and topography of the western arm of Saint Andrew's Bay, Fla. Measurement of base-lines at Saint Joseph's Bay and Saint Andrew's Bay. (See also Sections I and II.)
	5	Astronomical observations.	A. T. Mosman, assistant; Edwin Smith, aid.	Latitude and azimuth determined at Davis Point, Saint Andrew's Bay, Fla. (See also Sections III and IV.)

Distribution of surveying parties upon the Atlantic, Gulf, and Pacific coasts, &c.—Continued.

Coast sections.	Parties.	Observations.	Persons conducting operations.	Localities of work.
SECTION VII—Continued.	No. 6	Triangulation, topography, and hydrography.	H. G. Ogden, sub assistant; O. H. Tittmann, sub-assistant; S. N. Ogden, aid.	Complete survey of Santa Rosa Sound, Fla., including the Gulf coast from Choctawhatchee entrance westward to Pensacola Bay. (See also Sections I, II, and VIII.)
	7	Astronomical observations.	Edward Goodfellow, assistant....	Latitude, longitude, and the magnetic elements determined at Cleveland, in Ohio, and at Falmouth, in Kentucky. (See also Section II.)
	8	Astronomical observations.	G. W. Dean, assistant; A. T. Mosman, assistant; Edwin Smith, aid.	Latitude, longitude, and the magnetic elements determined at Columbus, Ohio. (See also Sections III and IV.)
	9	Astronomical observations.	A. T. Mosman, assistant; Edwin Smith, aid.	Latitude, longitude, and the magnetic elements determined at Oakland and at Shelbyville, Ky. (See also Sections III and IV.)
SECTION VIII. Gulf coast and bays of Alabama, and the sounds of Mississippi and Louisiana, to Vermilion Bay, including the ports and rivers.	1	Triangulation, topography, and hydrography.	C. H. Boyd, assistant; Joseph Hergesheimer, aid; C. H. Van Orden, aid.	Topography of the west side of Chandeleur Sound, including Live-Oak Bayou. Complete survey of the Mississippi River, extended from Grand Prairie upward to Point La Hache. (See also Section I.)
	2	Hydrography	J. S. Bradford, assistant; C. P. Dillaway, aid; T. J. Lowry, aid.	Hydrography of the eastern part of Lake Pontchartrain; deep-sea soundings in the approaches of the Mississippi Delta; soundings on Trinity Shoal, in the Gulf of Mexico. (See also Section I.)
	3	Triangulation.....	R. E. Halter, assistant; William Eimbeck, sub-assistant; O. H. Tittmann, sub-assistant.	Triangulation across the Mississippi River from stations in Illinois and Missouri, including the vicinity of Saint Louis. (See also Sections III, VII, and IX.)
SECTION IX. Gulf coast of Western Louisiana and of Texas, including bays and rivers.	1	Hydrography.....	F. D. Granger, sub-assistant; F. W. King, aid.	Soundings completing the hydrography of Matagorda and Lavaca Bays, and including the upper part of Espiritu Santo Bay, Tex. (See also Section II.)
	2	Astronomical observations.	R. Keith, observer; William Eimbeck, sub-assistant.	Latitude and longitude determined at Chetopa, Kans., by transits in the prime vertical and exchange of time-signals by telegraph from Saint Louis, Mo. (See also Section VIII.)
SECTION X. Pacific coast of California, including the bays, harbors, and rivers.	1	Astronomical observations.	George Davidson, assistant.......	Determination of positions for a hydrographic reconnaissance of the coast approaches north of Panama. Observations for longitude and for the magnetic elements at San Diego, Cal. (See also Section XI.)
	2	Hydrography.....	Gershom Bradford, sub-assistant; F. Westdahl.	Shore-line survey and hydrography of Magdalena Bay, in Lower California. (See also Section XI.)
		Hydrography.....	Commander Philip C. Johnson, U. S. N., assistant; Lieut. Commander C. W. Kennedy; Lieut. M. S. Day; Masters H. B. Mansfield and E. W. Remey.	Hydrographic party organized to continue off-shore soundings along the coast of California.
		Triangulation.....	George Davidson, assistant; H. I. Willey, aid.	Triangulation at Bahia Ona, and determination of the position of Santa Barbara Island in relation to the coast of California. Reconnaissance of the coast from San Diego northward to Point Dume. (See also Section XI.)
		Triangulation and topography.	A. W. Chase, sub-assistant........	Plane-table survey of the shore of Bahia Ona north of Point Vincente, and of part of Santa Barbara Island, Cal. (See also Section XI.)
		Triangulation and topography.	Stehman Forney, sub-assistant....	Topographical survey of San Miguel Island, in Santa Barbara Channel, Cal.

Distribution of surveying parties upon the Atlantic, Gulf, and Pacific coasts, &c.—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work
SECTION X—Continued.	No. 7	Topography	W. E. Greenwell, assistant........	Detailed survey of the coast of California from Point Pelican, near Santa Barbara, westward toward Point Conception.
	8	Topography	L. A. Sengteller, sub-assistant	Plane-table survey of the shores of San Luis Obispo Bay, Cal.
	9	Topography	Cleveland Rockwell, assistant; G. H. Wilson, aid.	Topography of the shores of San Simeon Bay, Cal., and adjacent coast to the westward. (See also Section XI.)
	10	Hydrography	Gershom Bradford, sub-assistant ..	Hydrographic exploration to determine the position of Falmouth Shoal, or Reed Rocks, off the coast of California. Comparative soundings and observations on currents near the Golden Gate. (See also Section XI.)
	11	Topography	Aug. F. Rodgers, assistant; E. F. Dickins, aid.	Topographical survey of Table Mountain, on the north side of San Francisco entrance. Wharf-lines traced as now existing at Oakland Point.
	12	Astronomical observations.	George Davidson, assistant	Station in San Francisco occupied for exchange of clock-signals, to determine the longitude of Seattle, W. T. Special comparison of coin weights at the United States branch mint in San Francisco.
	13	Hydrography	George Davidson, assistant; G. Farquhar, sub-assistant; S. R. Throckmorton and H. I. Willey, aids.	Hydrographic survey of Blossom Rock, in San Francisco Bay. Rocks determined in position in Mission Bay, and the positions of buoys off the Golden Gate. (See also Section XI.)
	14	Triangulation and topography.	L. A. Sengteller, sub-assistant	Detailed survey of the coast of California from Cuffey's Cove northward to Mendocino Bay.
	15	Triangulation and topography.	Aug. F. Rodgers, assistant; E. F. Dickins, aid.	Topographical survey from Cape Mendocino southward beyond Shelter Cove, Cal. Position determined of a sunken rock south of Punta Gorda.
	16	Triangulation and topography.	A. W. Chase, sub-assistant........	Topographical survey of the coast of California from the False Klamath north to the vicinity of Crescent City. Discovery and development of a rock in Crescent City Bay. (See also Section XI.)
	17	Astronomical observations.	George Davidson, assistant; S. R. Throckmorton, aid; H. I. Willey, aid.	Azimuth and magnetic elements determined at Eureka, and azimuth at Crescent City, Cal. Views of Cape Mendocino and Cape Fortunas, and of Orford Reef, with the adjacent coast. (See also Section XI.)
	18	Tidal observations.	Maj. G. H. Mendell, United States Engineers; William Knapp; F. P. Thompson.	Series of observations continued with the self-registering tide-gauges at San Diego and at Fort Point, near San Francisco, Cal. (See also Section XI.)
SECTION XI. Pacific coast of Oregon and of Washington Territory, including the interior bays, ports, and rivers.	1	Triangulation and topography.	A. W. Chase, sub-assistant........	Detailed survey of the coast of Oregon between Chetko River and Cape San Sebastian. (See also Section X.)
	2	Hydrography	Gershom Bradford, sub-assistant..	Hydrography of the Orford Reef, off the coast of Oregon. (See also Section X.)
	3	Topography	Cleveland Rockwell, assistant; G. H. Wilson, aid.	Topographical survey of the shores and islands of the Columbia River, between Cathlamet Point and Puget Island. (See also Section X.)
	4	Triangulation and topography.	J. J. Gilbert, sub-assistant........	Detailed survey of the entrance and northern shores of Shoalwater Bay, W. T.
	5	Astronomical observations.	George Davidson, assistant; S. R. Throckmorton, aid; H. I. Willey, aid.	Longitude of Seattle, W. T., ascertained by exchange of clock-signals with San Francisco. Magnetic elements determined. (See also Section X.)

Distribution of surveying parties upon the Atlantic, Gulf, and Pacific coasts, &c.—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION XI—Continued.	No. 6	Triangulation, topography, and hydrography.	James S. Lawson, assistant; Eugene Ellicott, sub-assistant; F. A. Lawson, aid.	Triangulation of the eastern part of the Strait of Fuca, including the entrance to Admiralty Inlet and Kilisut Harbor, Wash. Measurement of base-line on Nisqually Plains. Topography of the west end of Whidbey Island, including part of Penn's Cove. Hydrography of Partridge Bank, Lawson Reef, and Belle Rock. (See also Section IV.)
	....	Tidal observations.	Maj. G. H. Mendell, United States Engineers; L. Wilson.	Series continued with the self-registering tide-gauge at Astoria, Oreg. (See also Section X.)
SECTION XII. Coast of Alaska Territory, including the Aleutian Islands.	1	Astronomical observations and hydrography.	W. H. Dall, acting assistant; M. W. Harrington.	Party organized to determine geographical positions, and to make local surveys along the coast and islands of Alaska Territory.
		Tidal observations.	W. H. Dall........................	Series of tidal observations commenced with a self-registering gauge at Ilioulіouk, on the Aleutian Islands, Alaska.

APPENDIX No. 2.

Information furnished from the Coast Survey Office, by tracings from original sheets, &c., in reply to special calls, during the year ending November, 1871.

Date.		Name.	Data furnished.
1871.			
January	5	Col. J. H. Simpson, Corps of Engineers	Topographical survey of the western coast of Florida, from Saint Vincent's Island to Saint Joseph's Point, including the shores of Saint Joseph's Bay.
	6	Maj. T. J. Treadwell, United States Army	Topographical survey of Frankford arsenal and vicinity, Delaware River.
	13	Col. Thomas L. Casey, Corps of Engineers	Topographical survey of the west side of the Narragansett Bay, from South Ferry to Narragansett Pier.
	16	Thomas A. Scott, esq	Topographical survey coast of California, from the Santa Clara River to Point Mugu.
February	4	Col. W. P. Craighill, Corps of Engineers	Hydrographic survey of the Rappahannock River, from Farleyvale to Castle's Ferry, together with the survey of the bars, vicinity of Millbank and Tobago Bay.
	4	do do	Tidal information of the Rappahannock River, Va.
	4	Hon. Hamilton Fish, Secretary of State	Topographical and hydrographic survey of the Hudson River, from Anthony's Nose to Phillipse's Point.
	4	Capt. C. W. Howell, Corps of Engineers	Hydrographic survey of Pass Cavallo and Aransas Pass, Tex.
	7	Hon. James Buffinton, Mass	Topographical and hydrographic survey of Fall River, Mass.
	25	A. H. Richards, esq	Latest information about Little Egg Harbor, N. J.
	27	Light-House Board	Topographical survey of Point Reyes, Cal.
March	11	R. P. Paul, esq	Hydrographic survey of part of the Darien River and Catfish Bar, Ga.
	11	Col. Thomas L. Casey, Corps of Engineers	Topographical survey of the west side of Narragansett Bay, from South Ferry to Big Rock Point.
	11	Lieut.-Col. J. G. Foster, Corps of Engineers	Hydrographic survey of Wellfleet Harbor, Mass.
	11	do do	Projection, scale $\frac{1}{20000}$, and points of Wellfleet Harbor, Mass.
April	6	Col. J. H. Simpson, Corps of Engineers	Hydrographic survey of part of Tampa Bay, Fla.
	27	Col. George Thom, Corps of Engineers	Hydrographic survey of the Kennebec River, from Richmond to Gardiner, Me.
May	4	Department of Docks, N. Y	Shore-line surveys of Sandy Hook of 1855 and 1862.
	8	Maj. G. K. Warren, Corps of Engineers	Hydrographic survey of Norwalk Harbor, Conn.
	11	Providence Daily Journal, R. I	Distances and geographical positions in Narragansett Bay, R. I.
	11	Providence Evening Bulletin	Do. Do.
	11	Newport Mercury	Do. Do.
	11	Newport Daily News	Do. Do.
	17	Maj. G. K. Warren, Corps of Engineers	Projections, scale $\frac{1}{2500}$, of Port Jefferson Harbor and mouth of the Housatonic River, Conn.
	22	Col. George Thom, Corps of Engineers	Topographical survey coast of Maine, vicinity of Well's Harbor.
June	15	Professor N. S. Shaler, State geologist of Mass	Entire topographical survey of the island of Rhode Island.
July	10	Captain C. F. Hall	Sketch of the Polar regions.
	11	Lieut.-Col. J. D. Kurtz, Corps of Engineers	Hydrographic and topographical survey of the Delaware River, from Fort Mifflin to Cooper's Point, from surveys of 1843.
	11	do do	Compiled map of League Island and vicinity.
	11	do do	Shore-line survey of the Delaware River, from Red Bank to Kaighn's Point, 1870.
	11	do do	Hydrographic survey of the Delaware River, from Fort Mifflin to Red Bank, survey of 1861–'62.
	11	Appointment office, Treasury Department	Charts of the Atlantic, Gulf, and Pacific coasts, with lights colored.
	19	Col. George Thom, Corps of Engineers	Topographical survey coast of Maine, Webhannet River and vicinity.
	24	Maj. G. K. Warren, Corps of Engineers	Hydrographic and topographical survey of Huntington Harbor, N. Y.
August	3	do do	Shore-line survey of Bridgeport Harbor and Pequanok River to paper factory.
	10	John Halliday, esq., civil engineer	Hydrographic survey of Corpus Christi Pass, Tex.
	19	E. A. Marshall, esq	Topographical and hydrographic survey of entrance to Bull and Combahee Rivers, S. C.
	23	Board of trustees, town of San Diego, Cal	Hydrographic and topographical survey of San Diego Bay.
	30	Capt. A. N. Damrell, Corps of Engineers	Shore-line survey of St. George's Sound and trigonometrical points, Fla.

Information furnished from the Coast Survey Office, by tracings, &c.—Continued.

Date.		Name.	Data furnished.
1871.			
August	31	T. S. Hardee, State engineer of Mississippi	Hydrographic survey of Isle au Breton Sound and approaches, La.
	31	do do	Shore-line survey of the Mississippi River, from △ Point Tiger to △ Point Bohemia.
October	4	Daniel T. Van Buren, New York	Topography of the western shore of the Hudson River, from Whiskey Point to Kingston Point.
	11	Light-House Board	Topographical survey of Point San Pablo, Cal.
	11	Col. George Thom, Corps of Engineers	Hydrographic survey of Duxbury Bay, Mass.
	26	Department of Docks, New York	Topographical survey of the upper part of Manhattan Island, N. Y.
	30	S. T. Williams, New York	Force of current off Catharine and Wall Street ferries, N. Y.
	30	James F. Stuart, esq., California	Topographical survey of the coast of California, from near San Buenaventura to Point Mugu.
November	6	Col. George Thom, Corps of Engineers	Hydrographic approaches to Seal Harbor, coast of Maine, showing south breaker.

APPENDIX No. 3.

DRAWING DIVISION.

Charts completed or in progress during the year ending October 31, 1871.

1. Hydrography. 2. Topography. 3. Drawing for photographic reduction. 4. Details on photographic outlines. 5. Verification. 6. Lettering.

Title of chart.	Scale.	Draughtsmen.	Remarks.
General coast chart No. I, Quoddy Head, Me., to Cape Cod, Mass.	1-400, 000	1, 2. A. Lindenkohl. 2. H. Lindenkohl.	Additions.
Damariscotta and Medomak Rivers, Me	1-40, 000	1. L. Karcher	Completed.
Coast chart No. 4, Naskeag Point to White Head light, including Penobscot Bay, Me.	1-80, 000	3. F. Smith. 4. H. Lindenkohl.	
Casco Bay, Me	1-40, 000	1. A. Lindenkohl. 2. H. Lindenkohl.	Additions; completed.
Coast chart No. 6, Seguin Island light to Wood Island light, Me	1-80, 000	1. A. Lindenkohl. 3. F. Smith. 4. P. Erichsen. 5. P. Erichsen.	
Coast chart No. 7, Seguin Island light to Cape Porpoise light, Me	1-80, 000	3. F. Smith. 3. F. Fairfax. 4. P. Erichsen.	Additions; completed.
Portland Harbor, Me	1-20, 000	2. H. Lindenkohl	Additions; completed.
Coast chart No. 8, Boon Island light to Gloucester Harbor, Mass.	1-80, 000	1. A. Lindenkohl. 3. F. Smith. 4. P. Erichsen.	Additions; completed.
Coast chart No. 10, Cape Cod Bay, Mass	1-80, 000	1. A. Lindenkohl	New edition of hydrography; completed.
Plymouth Harbor, Mass	1-20, 000	1, 2. H. Lindenkohl	Additions.
General coast chart No. II, Cape Ann to Gay Head, Mass	1-400, 000	1. A. Lindenkohl. 2. H. Lindenkohl.	New edition of hydrography; completed.
Coast chart No. 13, Narraganset Bay, R. I	1-80, 000	3. F. Smith. 4. H. Lindenkohl. 4. P. Erichsen.	
Narraganset Bay, R. I., (upper sheet)	1-40, 000	2. W. Kilp. 3. F. Smith. 2. F. Fairfax. 2. P. Erichsen.	Additions; completed.
Narraganset Bay, R. I., (lower sheet)	1-40, 000	2. H. Lindenkohl	Completed.
New Bedford Harbor, Mass	1-40, 000	2. H. Lindenkohl	Additions; completed.
New York Bay and Harbor, (upper sheet)	1-40, 000	1. A. Lindenkohl. 2. L. Karcher. 2. F. Fairfax. 2. P. Erichsen. 2. F. Smith.	Completed.
Coast chart No. 21, Sandy Hook to Barnegat light, N. J	1-80, 000	2. H. Lindenkohl.	
Coast chart No. 29, Chincoteague Inlet to Hog Island light, Va	1-80, 000	1, 2. H. Lindenkohl	Completed.
Coast chart No. 30, Hog Island light to Cape Henry, Va	1-80, 000	1, 2. H. Lindenkohl.	
General coast chart No. IV, Cape May to Cape Henry	1-400, 000	1, 2. A. Lindenkohl	Additions.
Coast chart No, 34, Chesapeake Bay, Potomac River to Choptank River, Md.	1-80, 000	2. H. Lindenkohl	Additions; completed.
Platt Shoals, N. C	1-80, 000	1. L. Karcher	Completed.
General coast chart No. V, Cape Charles to Cape Lookout, N. C.	1-400, 000	1, 2. A. Lindenkohl	Additions.
Coast chart No. 50, Cape Fear River, Frying-Pan Shoals, N. C	1-80, 000	1, 2. A. Lindenkohl.	
Atlantic coast No. III, Cape Hatteras to Mosquito Inlet	1-1, 200, 000	1. A. Lindenkohl	Additions; completed.
Coast chart No. 54, Long Island to Hunting Island, including Charleston Harbor, S. C.	1-80, 000	2 H. Lindenkohl	Additions; completed.
Coast chart No. 55, Hunting Island to Ossabaw Sound, including Savannah River, Ga.	1-80, 000	1, 2. H. Lindenkohl	Additions; completed.
Saint Helena Sound, S. C	1-40, 000	1, 2. H. Lindenkohl	Additions; completed.
Inside Passage between Saint Helena Sound and Port Royal Sound, S. C.	1-40, 000	2. W. Kilp	Completed.
Entrance to Bull and Combahee Rivers, S. C	1-40, 000	1, 2. F. Smith	Completed.
Savannah River and Wassaw Sound, Ga	1-40, 000	2. F. Fairfax.	
Atlantic coast No. IV, Mosquito Inlet to Key West, Fla	1-1, 200, 000	1. A. Lindenkohl	Additions; completed.
Coast chart No. 56, Savannah River to Doboy light, Ga	1-80, 000	1. A. Lindenkohl. 1. H. Lindenkohl	Completed.
Doboy and Altamaha Sounds, Ga	1-40, 000	1. H. Lindenkohl. 2. F. Fairfax.	
Saint Andrew's Sound, Ga	1-40, 000	1, 2. F. Fairfax.	
General coast chart No. VII, Cape Roman to Saint Mary's River, Fla.	1-400, 000	1. A. Lindenkohl	Additions; completed.
Coast chart No. 57, Doboy Sound to Fernandina, Fla	1-80, 000	1. A. Lindenkohl. 2. H. Lindenkohl.	
Saint Mary's River and Fernandina Harbor, Fla	1-20, 000	1. A. Lindenkohl	Additions; completed.
Key West Harbor, Fla	1-50, 000	2. P. Erichsen	Additions; completed.
Coast chart No. 69, Newfound Harbor Key to Boca Grande Key, Fla.	1-80, 000	2. P. Erichsen	Additions; completed.
General coast chart No. X, Straits of Florida	1-400, 00	1. A. Lindenkohl	Additions; completed

Charts completed or in progress during the year, &c.—Continued.

Title of chart.	Scale.	Draughtsmen.	Remarks.
Gulf of Mexico, (eastern part)	1-1, 200, 000	1. A. Lindenkohl	Additions; completed.
Coast chart No. 86, Choctawhatchee Entrance to Pensacola Bay, Fla.	1-80, 000	1. H. Lindenkohl. 2. P. Erichsen	Completed.
Coast chart No. 91, Lakes Borgne and Pontchartrain, La	1-80, 000	1. H. Lindenkohl.	
Coast chart No. 94, Mississippi River Delta	1-80, 000	2. A. Lindenkohl.	
Coast chart No. 107, Matagorda and Lavaca Bays, Tex	1-80, 000	1. A. Lindenkohl. 2. L. Karcher	Completed.
Corpus Christi Pass, Tex	1-40, 000	1. L. Karcher	Completed.
Santa Barbara Channel, chart No. 2	1-200, 000	1, 2. A. Lindenkohl and H. Lindenkohl.	
San Francisco Peninsula, Cal	1-40, 000	2. H. Lindenkohl. 2. F. Fairfax. 2. P. Erichsen.	Completed.
Entrance to San Francisco Bay, Cal	1-50, 000	1. L. Karcher	Additions; completed.
Suisun Bay, Cal	1-40, 000	2. H. Lindenkohl	Completed.
Saint George's Reef and Crescent City, Cal	1-40, 000	1, 2. H. Lindenkohl. 2. A. Lindenkohl.	
Columbia River Entrance	1-40, 000	2. F. Fairfax	Completed.
Columbia River, (sheet No. 2)	1-40, 000	1. L. Karcher.	
Washington Sound, (new edition)	1-200, 000	2. A. Lindenkohl	Additions; completed.
Northwest chart No. II, Dixon Entrance to Cape Saint Elias	1-1, 200, 000	1, 2. A. Lindenkohl.	
Northwest chart No. III, Icy Bay to Seven Islands	1-1, 200, 000	1, 2. A. Lindenkohl.	

APPENDIX No. 4.

ENGRAVING DIVISION.

Plates completed, continued, or commenced during the year 1871.

1. Outlines. 2. Topography. 3. Sanding. 4. Lettering.

Title of plate.	Scale.	Engravers.
COMPLETED.		
Northwest coast of America No. 2, (prelim. ed.)	1-1, 200, 000	4. F. Courtenay.
Northwest coast of America No. 3, (prelim. ed.)	1-1, 200, 000	4. F. Courtenay.
Coast chart No. 8, Well's to Cape Ann	1-80, 000	2. A. Sengteller. 3. H. S. Barnard. 4. J. Knight.
Coast chart No. 9, Boston Bay	1-80, 000	Views, George McCoy. 4. E. A. Maedel.
Coast chart No. 28, Isle of Wight to Chincoteague	1-80, 000	4. J. Knight.
Coast chart No. 54, Long Island, S. C., to Hunting Island	1-80, 000	1 and 2. A. Sengteller. 3. H. S. Barnard. 4. J. Knight.
Coast chart No. 105, Galveston to Oyster Bay	1-80, 000	4. A. Petersen.
Fox Islands Thoroughfare	1-20, 000	4. J. G. Thompson.
Casco Bay	1-40, 000	2. W. A. Thompson. 4. A. Petersen.
Portland Harbor, (new ed.)	1-20, 000	1 and 2. A. M. Maedel. 3. H. M. Knight. 4. W. H. Davis.
Boston Harbor, (new ed.)	1-40, 000	3. F. W. Benner. 4. F. Courtenay. Views, George McCoy
Wickford Harbor	1-20, 000	3. F. W. Benner. 4. J. G. Thompson and E. H. Sipe.
Patapsco River, (new ed.)	1-60, 000	4. J. G. Thompson.
Potomac River No. 2	1-60, 000	2. A. M. Maedel. 4. A. Petersen.
Saint Catharine's Sound	1-40, 000	2. W. A. Thompson.
Platt Shoals	1-80, 000	1, 3, and 4. E. H. Sipe.
Saint Mary's River and Fernandina Entrance, (new ed.)	1-20, 000	1 and 3. H. M. Knight. 4. W. H. Davis.
Corpus Christi Pass	1-40, 000	1 and 4. W. H. Davis.
San Francisco Peninsula	1-40, 000	1. J. C. Kondrup and E. Molkow. 2. W. A. Thompson. 4. A. Petersen and F. Courtenay.
Saint George's Reef and Crescent City, (prelim. ed.)	1-40, 000	1 and 4. J. G. Thompson. 3. F. W. Benner.
Cape Orford and reef, (prelim. ed.)	1-40, 000	1 and 2. W. A. Thompson. 3. F. W. Benner. 4. J. G. Thompson.
Yaquina River Entrance, (prelim. ed.)	1-40, 000	3. H. M. Knight. 4 J. G. Thompson and E. H. Sipe.
Columbia River No. 1, (prelim. ed.)	1-40, 000	3. F. W. Benner. 4. J. G. Thompson and E. H. Sipe.
CONTINUED.		
General coast chart No. I, Quoddy Head to Cape Cod	1-400, 000	1 and 2. J. Enthoffer.
General coast chart No. IV, Cape May to Cape Henry	1-400, 000	1 and 2. A. M. Maedel.
General coast chart No. V, Cape Henry to Cape Lookout	1-400, 000	1 and 2. A. M. Maedel. 3. H. S. Barnard. 4. A. Petersen.
General coast chart No. VII, Cape Roman to Saint Mary's River.	1-400, 000	2. A. M. Maedel.
General coast chart No. X, Straits of Florida	1-400, 000	2. J. C. Kondrup.
General coast chart No. XIII, Cape San Blas to Mississippi Delta.	1-400, 000	1 and 2. A. M. Maedel. 3. H. M. Knight.
Coast chart No. 4, Penobscot Bay	1-80, 000	1 and 2. J. Enthoffer.
Coast chart No. 5, Whitehead Light to Seguin Light	1-80, 000	4. E. A. Maedel.
Coast chart No. 6, Seguin Light to Fletcher's Neck	1-80, 000	1 and 2. J. Enthoffer.
Coast chart No. 7, Cape Small to Kennebunkport	1-80, 000	1 and 2. J. Enthoffer.
Coast chart No. 10, Cape Cod Bay	1-80, 000	4. F. Courtenay. Views, G. McCoy.
Coast chart No. 13, Narragansett Bay, &c	1-80, 000	1 and 2. J. Enthoffer.
Coast chart No. 30, entrance to Chesapeake Bay	1-80, 000	1 and 2. H. C. Evans.
Coast chart No. 31, Chesapeake Bay No. 1	1-80, 000	1 and 2. H. C. Evans.
Coast chart No. 32, Chesapeake Bay No. 2	1-80, 000	1 and 2. H. C. Evans. 3. F. W. Benner. 4. J. Knight.
Coast chart No. 50, Cape Fear and approaches	1-80, 000	1 and 2. A. M. Maedel. 4. J. Knight.
Coast chart No. 55, Hunting Island to Ossabaw	1-80, 000	1 and 2. A. Sengteller. 3. H. S. Barnard.
Coast chart No. 56, Savannah to Doboy Light	1-80, 000	2. A. Sengteller. 4. E. A. Maedel.
Coast chart No. 75, Charlotte Harbor, &c	1-80, 000	3. H. M. Knight. 4. J. Knight.
Coast chart No. 94, Mississippi River Entrance	1-80, 000	1 and 2. A. M. Maedel. 3. H. M. Knight. 4. J. Knight.
Coast chart No. 107, Matagorda Bay	1-80, 000	1 and 2. J. C. Kondrup. 4. A. Petersen.
Saint George's River and Muscle Ridge Channel	1-40, 000	1. E. Molkow and J. C. Kondrup.
Damariscotta and Medomak Rivers	1-40, 000	4. A. Peterson.

Plates completed, continued, or commenced, &c.—Continued.

Title of plate.	Scale.	Engravers.
Narraganset Bay, (upper)	1-10, 000	2. H. C. Evans. 3. F. W. Benner. 4. A. Petersen.
Narraganset Bay, (lower)	1-40, 000	1. E. Molkow, J. C. Kondrup, and W. A. Thompson. 2. H. C. Evans. 4. A. Petersen and E. A. Maedel.
New York Bay and Harbor, (upper)	1-40, 000	2. R. F. Bartle. 4. E. A. Maedel.
New York Bay and Harbor, (lower)	1-40, 000	2. R. F. Bartle. 3. H. M. Knight. 4. E. A. Maedel.
Inside passage between Port Royal and Saint Helena Sounds	1-40, 000	1. J. G. Thompson.
COMMENCED.		
Coast chart No. 57, Doboy Light to Fernandina	1-80, 000	1. A. Sengteller.
Penobscot Bay, (west)	1-40, 000	1. E. Molkow.
Platt Shoals	1-80, 000	1, 3, and 4. E. H. Sipe.
Doboy and Altamaha Sounds	1-40, 000	1 and 4. E. H. Sipe.
Corpus Christi Pass	1-40, 000	1 and 4. W. H. Davis.
Saint George's Reef and Crescent City	1-40, 000	1 and 4. J. G. Thomspon.
Cape Orford and reef	1-40, 000	1 and 2. W. A. Thompson. 4. J. G. Thompson.

APPENDIX No. 5.

List of original topographical sheets registered in the archives of the United States Coast Survey from January 1, 1866, to December 31, 1871.

Localities.	State.	Scale.	Date.	Topographer.	Register number.
Letite Passage and vicinity	New Brunswick	1-10, 000	1865	W. H. Dennis	1007
Saint Croix River, (Calais and Saint Stephen's)	Maine and New Brunswick.	1-10, 000	1869	......do	1150
West Quoddy Bay	Maine	1-10, 000	......	......do	980
Moose-a-bec Reach, (middle sheet)	....do	1-10, 000	1870	J. W. Donn	1171
Moose-a-bec Reach, (upper sheet)	....do	1-10, 000	1870	......do	1172
Moose-a-bec Reach, (lower sheet)	....do	1-10, 000	1870	......do	1173
Gouldsborough Bay	....do	1-10, 000	1865	C. Rockwell	1039
Winter Harbor to Gouldsborough Bay	....do	1-10, 000	1865	......do	1040
North Haven Island, including Ledges and Island north of Main and Little Thoroughfares.	....do	1-10, 000	1867	F. W. Dorr	1072
Northern part of Vinal Haven Island, with Stimpson's, Calderwood's, and Babbage Islands.	....do	1-10, 000	1868	......do	1075
Penobscot Bay; islands south of Isleboro	....do	1-10, 000	1870	A. W. Longfellow	1167
Fox Islands, western part of	....do	1-10, 000	1868	F. W. Dorr	1093
Fox Islands, southeast part of	....do	1-10, 000	1870	H. M. De Wees	1157*a*
Fox Islands, southeast part of, and Smith, Saddleback, and Brimstone Islands.	....do	1-10, 000	1870	......do	1157*b*
Rockland Harbor and vicinity	....do	1-10, 000	1870	W. H. Dennis	1160
Friendship	....do	1-10, 000	1867	Charles Hosmer	1058
Seal, Tennant's, and Mosquito Harbors	....do	1-10, 000	1868	W. H. Dennis	1081
Saint George's River entrance	....do	1-10, 000	1869	F. W. Dorr	1117
Saint George's River	....do	1-10, 000	1868	Charles Hosmer	1116
Weskeag River and vicinity	....do	1-10, 000	1869	W. H. Dennis	1151
Merrymeeting Bay, including Androscoggin, Muddy, and Cathance Rivers.	....do	1-10, 000	1871	C. H. Boyd	1214
Muscongus Bay, islands and ledges	....do	1-10, 000	1865	F. W. Dorr	1001
Muscongus Bay, southern part	....do	1-10, 000	1865	......do	1002
Muscongus Bay, from Round Pond to Hocamoc	....do	1-10, 000	1866	C. Rockwell	1028
Pemmaquid Neck, including John's Bay and Pemmaquid River.	....do	1-10, 000	1866	F. W. Dorr	1032
Pemmaquid Point, including New Harbor and west shore of Muscongus Bay.	....do	1-10, 000	1866	......do	1033
Medomak River	....do	1-10, 000	1867-'68	Charles Hosmer	1076
Linekin's Bay and islands at mouth of Damariscotta River	....do	1-10, 000	1865	F. W. Dorr	1000
Kennebec River, head of	....do	1-10, 000	1859, '65	R. M. Bache	1061
Kennebec River, from Abagadasset Point to Richmond	....do	1-10, 000	1869	C. H. Boyd	1115
Kennebec River, from Richmond to Gardiner	....do	1-10, 000	1870	......do	1158
New Meadow River, from Forster's Point to New Meadow Bridge.	....do	1-10, 000	1866	J. W. Donn	1021
Casco Bay, from Middle Bay to New Meadow River, including north end of Sebaskahegan Island.	....do	1-10, 000	1867, '69	A. W. Longfellow	1129
Casco Bay, Sebaskahegan and Orr's Islands	....do	1-10, 000	1865	......do	1012
Casco Bay, sketch of Half-Way Rock	....do	1-2, 000	1867	C. H. Boyd	1056
Portland Harbor, wharf, and shore-line	....do	1-5, 000	1867	A. W. Longfellow and H. W. Bache.	1111
Portland City and Harbor, special survey, sheet No. 1	....do	1-1, 200	1868-'69	A. Lindenkohl	1140*a*
Portland City and Harbor, special survey, sheet No. 2	....do	1-1, 200	1868-'69	......do	1140*b*
Portland City and Harbor, special survey, sheet No. 3	....do	1-1, 200	1868-'69	......do	1141*a*
Portland City and Harbor, special survey, sheet No. 4	....do	1-1, 200	1869	Charles Hosmer	1141*b*
Portland City and Harbor, special survey, sheet No. 5	....do	1-1, 200	1869	......do	1142*a*
Portland City and Harbor, special survey, sheet No. 6	....do	1-1, 200	1869	J. W. Donn	1142*b*
Portland City and Harbor, special survey, sheet No. 7	....do	1-1, 200	1869	......do	1143*a*
Portland City and Harbor, special survey, sheet No. 8	....do	1-1, 200	1869	Charles Hosmer	1143*b*
Portland City and Harbor, special survey, sheet No. 9	....do	1-1, 200	1869	J. W. Donn	1144*a*
Portland City and Harbor, special survey, sheet No. 10	....do	1-1, 200	1869	J. N. McClintock	1144*b*
Mouth of Saco River and Biddeford Pool	....do	1-10, 000	1870	H. Adams	1168
Kennebunk Port and Cape Porpoise to Hoyt's Neck	....do	1-10, 000	1870	......do	1159

List of original topographical sheets registered in the archives, &c.—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Register number.
Coast from Ogunquit, in Wells, to Mousam River	Maine	1-10, 000	1869	H. Adams	1121
Coast from Kittery to York	...do	1-10, 000	1867	......do	1050
Coast from Boar's Head to Rye Harbor	New Hampshire	1-10, 000	1866	......do	1023
Coast from Rye Harbor to near Portsmouth	...do	1-10, 000	1867	......do	1047
Cape Cod Bay, western shore, from Ship Point to West Sandwich	Massachusetts	1-10, 000	1867	P. C. F. West	1062
Cape Cod Bay, western shore, from Eel River to Ship Point	...do	1-10, 000	1866	......do	1063
Cape Cod Bay, southern shore, from Orleans to Brewster	...do	1-10, 000	1868	H. Adams	1078
Cape Cod Bay, north shore, from North Dennis to Brewster	...do	1-10, 000	1868	P. C. F. West	1088
Cape Cod Bay, eastern shore, from Pleasant Bay to Nausett Harbor	...do	1-10, 000	1868	H. Adams	1077
Cape Cod, southern extremity, including village of Chatham	...do	1-10, 000	1868	H. W. Bache	1085*a*
Cape Cod, from Pleasant Point to Monomoy Island	...do	1-10, 000	1868	C. H. Boyd	1085*b*
Monomoy Point	...do	1-20, 000	1868	P. C. F. West	1090
City of Fall River and vicinity	...do	1-10, 000	1867	A. M. Harrison	1053
Town of East Greenwich and vicinity	Rhode Island	1-10, 000	1868	......do	1079
Mount Hope Bay, northern part	...do	1-10, 000	1865	......do	1024
City of Providence, wharf-line	...do	1-5, 000	1867	......do	1041
Prudence Island	...do	1-10, 000	1865	......do	1054
Narraganset Pier to South Ferry	...do	1-10, 000	1869	......do	1118
Seaconnet River, eastern part	...do	1-10, 000	1870	Charles Hosmer	1156
Seaconnet Point	...do	1-10, 000	1870	......do	1161
Island of Rhode Island, from Black Point to Easton Point	...do	1-10, 000	1870	H. G. Ogden	1163
Island of Rhode Island, northern part	...do	1-10, 000	1870	A. M. Harrison	1162
Newport and vicinity	...do	1-10, 000	1870-'71	......do	1194
Conanicut, Dutch, and Gould Islands	...do	1-10, 000	1869	......do	1119
Navy-yard near New London	Connecticut	1-1, 200	1869	H. G. Ogden	1107
Lake Champlain, from White's Landing to Appletree Point	Vermont	1-10, 000	1870	F. W. Dorr	1181
Lake Champlain, from Appletree Point to Hogback Island	...do	1-10, 000	1870	......do	1182
Lake Champlain, from Trembleau Point to Port Jackson	...do	1-10, 000	1870	......do	1183
Lake Champlain, from Trembleau Point to Ligonier Point	...do	1-10, 000	1870	F. W. Dorr & Ch. Hosmer	1185
Lake Champlain, vicinity of Plattsburgh	New York	1-10, 000	1870	Charles Hosmer	1184
Lake Champlain, vicinity of Plattsburgh	Vermont	1-10, 000	1870	......do	1186
Lake Champlain, vicinity of Mallett's Bay	...do	1-10, 000	1871	......do	1205
Lake Champlain, shore-line surveys	...do	1-10, 000	1871	......do	1206
Lake Champlain, shore-line surveys	...do	1-10, 000	1871	......do	1207
Lake Champlain, shore-line surveys	...do	1-10, 000	1871	......do	1208
Lake Champlain, shore-line surveys	...do	1-10, 000	1871	......do	1209
Lake Champlain, from Cumberland Head Point to Point-au-Roche	New York	1-10, 000	1871	H. G. Ogden	1217
Lake Champlain, the Gut and Point-au-Roche	...do	1-10, 000	1871	......do	1218
Lake Champlain, from Point-au-Roche to Long Point	...do	1-10, 000	1871	......do	1219
Lake Champlain, La Motte and Alburgh Passages	...do	1-10, 000	1871	......do	1220
Lake Champlain, from Isle La Motte to boundary-line	...do	1-10, 000	1871	......do	1221
Lake Champlain, part of Missisquoi Bay	Vermont	1-10, 000	1871	......do	1222
Lake Champlain, Missisquoi Bay south of boundary-line	...do	1-10, 000	1871	......do	1223
Hudson River, from Anthony's Nose to Cold Spring	New York	1-10, 000	1861	John Mechan	1010
Hudson River, from Cold Spring to Newburgh	...do	1-10, 000	1861	......do	1011
North and South Shrewsbury Rivers	New Jersey	1-10, 000	1865	C. M. Bache	1005
Shrewsbury River, south	...do	1-10, 000	1866	......do	1022
Coast between Deal and Squan Beach	...do	1-10, 000	1867	......do	1083
Coast between Squan village and Barnegat Bay	...do	1-10, 000	1868	......do	1084
Barnegat Inlet	...do	1-10, 000	1866	C. Fendall	1015
Absecum Inlet and vicinity	...do	1-20, 000	1869-'70	C. M. Bache	1166
Potomac River, from Saint George's River to Higgins' Point	Maryland	1-20, 000	1868	J. W. Donn	1103
Potomac River, from Clement's Bay to Swan Point	...do	1-20, 000	1868	......do	1105
Patapsco River, north shore, from Fort Marshall to Bear Creek	...do	1-10, 000	1866	C. T. Iardella	1034
Forts Chaplin, Mahan, and Sedgwick	District Columbia	1-10, 000	1865	C. M. Bache	1036
Arlington, part of, sheet No. 1	Virginia	1-1, 200	1864	E. Hergesheimer	1025
Arlington, part of, sheet No. 2	...do	1-1, 200	1864	......do	1026
Upper Potomac, from Lock No. 36 to High Knob	Maryland and Virginia.	1-10, 000	1866	J. W. Donn	1013
Upper Potomac, from High Knob to Shepherdstown	...do	1-10, 000	1865-'66	......do	1014
Yeocomico and Coan Rivers	Virginia	1-20, 000	1868	......do	1102
Nomini and Currioman Bays	...do	1-20, 000	1868	......do	1104
Mattox Creek and part of Nomini Creek	...do	1-20, 000	1868	......do	1106
Piankatank River	...do	1-20, 000	1869	......do	1100

List of original topographical sheets registered in the archives, &c.—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Register number.
Mobjack Bay, North, Ware, and Severn Rivers	Virginia	1–20, 000	1860, '68	G. D. Wise & J. W. Donn	1101
Newport News Point	....do	1–10, 000	1865	E. Hergesheimer	1008
East shore of Virginia, Broad water, sheet No. 3	....do	1–20, 000	1871	J. W. Donn	1200
East shore of Virginia, Broad water, sheet No. 4	....do	1–20, 000	1869–'70	......do	1201
East shore of Virginia, Broad water, sheet No. 2	....do	1–20, 000	1869–'70	......do	1202
East shore of Virginia, Broad water, sheet No. 1	....do	1–20, 000	1869–'70	......do	1203
East shore of Virginia, head of Machipongo River	....do	1–20, 000	1871	......do	1204
Pamplico River, from Rumley Marshes to Ragged Point	North Carolina	1–20, 000	1871	F. W. Dorr	1210
Pamplico River, from Mauls' Point to Rodman's Point	....do	1–20, 000	1871	......do	1211
Pamplico River, from Adams' Point to Rumley Marshes	....do	1–20, 000	1871	......do	1212
Pamplico River, from Light-house to Indian Island	....do	1–20, 000	1871	......do	1213
Bay River, Pamplico Sound	....do	1–20, 000	1869	......do	1094
Shore-line from Bay River to Pamplico Sound	....do	1–20, 000	1869	......do	1095
Neuse River, from New Berne to Johnson's Point	....do	1–10, 000	1866	......do	1031
Neuse River, from Johnson's Point to Beard's Creek	....do	1–20, 000	1866	......do	1018
Neuse River, from Beard's Creek to Wilkinson Point	....do	1–20, 000	1867	......do	1051
Neuse River, from Wilkinson Point to Cedar Point	....do	1–20, 000	1867	......do	1052
Neuse River, from Cedar Point to Brown's Creek	....do	1–20, 000	1868	......do	1073
Neuse River, from Brown's Creek to Point of Marsh	....do	1–20, 000	1868	......do	1074
Portsmouth Island and part of Core Beach	....do	1–20, 000	1866	C. Fendall	1016
Core Sound, northeast part of	....do	1–20, 000	1866	W. H. Dennis	1020
Core Sound, southwest part of	....do	1–20, 000	1866	......do	1017
Bogue Sound, from Broad Creek to Queen's Creek	....do	1–20, 000	1871	H. Adams	1215
Bogue Sound, part of	....do	1–10, 000	1867	A. W. Longfellow	1110
New Inlet, including Federal Point, Zeek's and Smith's Islands	....do	1–10, 000	1865	J. S. Bradford	999
Parry and Cane's Islands	South Carolina	1–20, 000	1868	C. Hosmer	1070
Port Royal and vicinity	....do	1–20, 000	1865	W. H. Dennis	1006
Broad River, southern part of	....do	1–20, 000	1865	R. E. Halter	998
Between Broad and May Rivers, containing hydrography	....do	1–20, 000	1870–'71	C. Hosmer	1195
Savannah River to Cooper River, west of Danfuskie Islet, containing hydrography.	....do	1–20, 000	1870–'71	......do	1196
Savannah River, Forts Jackson and Lee, Batteries Tatnall and Barnwell.	....do	1–5, 000	1866	C. O. Boutelle and H. L. Marindin.	1027
Romerly Marsh Creek	Georgia	1–20, 000	1869	C. Hosmer	1089
Ogeechee to Medway Bay	....do	1–20, 000	1869	......do	1109
Saint Catharine's Island and vicinity	....do	1–20, 000	1867	C. Rockwell and J. A. Sullivan.	1060
Between the Medway and Julienton Rivers	....do	1–20, 000	1869	C. Hosmer	1155
Doboy Sound and vicinity	....do	1–20, 000	1868	W. H. Dennis	1080
Altamaha Sound and vicinity	....do	1–20, 000	1869	......do	1114
Darien City	....do	1–20, 000	1869	......do	1114*bis*
Saint Simon's and Long Islands	....do	1–20, 000	1869	C. T. Iardella	1108
Mackay's River and vicinity	....do	1–20, 000	1869	W. H. Dennis	1113
Saint Andrew's Sound and vicinity	....do	1–20, 000	1869–'70	C. M. Bache	1145
Cumberland Island, part of	....do	1–20, 000	1870	W. H. Dennis	1152
Western arm of Saint Andrew's Bay	Florida	1–20, 000	1871	H. M. De Wees	1187
Coast from Saint Augustine to Matansas Inlet	....do	1–20, 000	1867	C. M. Bache	1082
Head of Key Biscayne Bay	....do	1–20, 000	1867	C. T. Iardella	1049
Shore and keys of Barnes' Sound	....do	1–30, 000	1868	......do	1071
Barnes' Sound	....do	1–40, 000	1870	J. G. Oltmanns	1154
Pine Island Sound, Charlotte Harbor	....do	1–20, 000	1866–'67	C. T. Iardella	1048
Saint Joseph's Bay, Cape San Blas and vicinity	....do	1–20, 000	1868	H. M. De Wees	1065
Saint Joseph's Bay to Saint Andrew's Point	....do	1–20, 000	1869	......do	1091
Saint Andrew's Bay, eastern and western branches	....do	1–20, 000	1870	C. T. Iardella	1146
Saint Andrew's Bay, northern branch	....do	1–20, 000	1870	......do	1147*a*
Saint Andrew's Bay, eastern branch	....do	1–20, 000	1870	......do	1147*b*
Choctawhatchee Bay and Santa Rosa Sound	....do	1–20, 000	1871	H. G. Ogden	1191
Santa Rosa Sound, from longitude 86° 43′ to 86° 58′	....do	1–20, 000	1871	......do	1192
Santa Rosa Sound, from longitude 86° 58′ to 87° 7′	....do	1–20, 000	1871	......do	1193
Coast between Pensacola to Mobile, west part of Big Lagoon	....do	1–10, 000	1867	J. G. Oltmanns	1034
Coast between Pensacola, from lagoon to mouth of Perdido Inlet	Florida and Alabama.	1–10, 000	1867	......do	1035
Coast between Pensacola, from Perdido Entrance to east Gulf shore.	....do	1–10, 000	1867	......do	1042

List of original topographical sheets registered in the archives, &c.—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Register number.
Entrance to Mobile Bay	Alabama	1–20, 000	1868	J. G. Oltmanns	1066
Chandeleur Sound, west side, from Morgan Harbor to Indian Mound Bay.	Louisiana	1–20, 000	1871	C. H. Boyd	1198
Isle au Breton Sound, Deep Water to California Point	do	1–20, 000	1868–'69	do	1096
Isle au Breton Sound, California Point to Mozambique Point	do	1–20, 000	1869	do	1098*a*
Isle au Breton Sound, California Point	do	1–20, 000	1869	do	1098*b*
Isle au Breton Sound, south side	do	1–20, 000	1869	do	1097
Isle au Breton Sound, Gardener's to Otter Bayou	do	1–20, 000	1869–'70	do	1099
Isle au Breton Sound, Otter Bayou to Point Comfort	do	1–20, 000	1870	do	1148
Isle au Breton Sound, Errol Island	do	1–20, 000	1869	do	1092
Mississippi Delta, Southwest Pass, part of South Pass, East, West, and Garden Island Bays.	do	1–20, 000	1867	J. W. Donn	1037
Mississippi Delta, South Pass, Bayou Grand, and East Pass	do	1–20, 000	1867	do	1038
Mississippi River, from Cubit Crevasse to the forts and Bird Island Sound.	do	1–20, 000	1868	C. H. Boyd	1069
Mississippi River, from the forts to Grand Prairie	do	1–20, 000	1870	do	1149
Mississippi River, from Grand Prairie to Point à la Hache	do	1–20, 000	1871	do	1197
Matagorda Island	Texas	1–20, 000	1859	W. H. Dennis	1030
Corpus Christi Bay, Corpus Christi to McGloin's Bluff	do	1–20, 000	1867	C. Hosmer	1043
Corpus Christi Bay, McGloin's Bluff to Mustang Island	do	1–20, 000	1867	do	1044
Laguna Madre, eastern shore	do	1–20, 000	1867	C. H. Boyd	1045
Laguna Madre, western shore	do	1–20, 000	1867	do	1046
Point San Pedro to Pillar Point	California	1–10, 000	1866	A. F. Rodgers	1019
Point Fermin to Point Saint Vincent	do	1–10, 000	1870	A. W. Chase	1153
Santa Barbara to Sand Point	do	1–10, 000	1869	W. E. Greenwell	1128
Sand Point to Gorda Point	do	1–10, 000	1869	do	1127
Punta Gorda toward Buenaventura	do	1–10, 000	1870	do	1189
Town of Buenaventura and vicinity	do	1–10, 000	1870	do	1190
Santa Cruz and Santa Barbara Channel	do	1–10, 000	1860	W. M. Johnson	1003
Santa Barbara Island	do	1–10, 000	1871	A. W. Chase	1180
Point Conception and vicinity, two sheets	do	1–10, 000	1869	C. Rockwell	1122 *a & b*
Point Sal, southern shore	do	1–5, 000	1867	W. E. Greenwell	1055
Coast from Tunitas Creek northward	do	1–10, 000	1866	A. F. Rodgers	1009
Land approaches to San Francisco	do	1–10, 000	1867	A. W. Chase	1059
Approaches to San Francisco	do	1–10, 000	1867	C. Rockwell	1067
Approaches to San Francisco	do	1–10, 000	1868	do	1068
Suisun Bay	do	1–20, 000	1866	A. F. Rodgers	1029
Humboldt Bay to Table Bluff	do	1–20, 000	1869	do	1137
Humboldt Bay, three sheets	do	1–10, 000	1870	do	1174, 1175, 1176
Coast north of Humboldt Bay	do	1–10, 000	1870	do	1177
Coast south of Trinidad Head	do	1–10, 000	1870	do	1178
Coast north of Trinidad Head	do	1–10, 000	1870	do	1179
Centreville to False Cape	do	1–10, 000	1869	do	1135
False Cape to Cape Mendocino	do	1–10, 000	1869	do	1134
Eel River and vicinity	do	1–10, 000	1869	do	1136*a*
Eel River changes from 1869 to 1870	do	1–10, 000	1869–'70	do	1136*b*
Point Saint George and Crescent City Reef	do	1–10, 000	1869	A. W. Chase	1132
From Point Saint George northward, (Lake Earl)	do	1–10, 000	1870	do	1199
From Cone Station to near Oregon boundary	do	1–10, 000	1870	do	1216
Coast of Oregon, near Port Orford, reconnaissance	Oregon	1–20, 000	1869	do	1133
Orford Reef	do	1–10, 000	1869	do	1131
Cape Blanco	do	1–10, 000	1869	do	1130
Cape Foulweather and entrance to Yaquina Bay	do	1–10, 000	1868	do	1086
Columbia River, from Point Adams to Young's Bay	do	1–10, 000	1868	C. Rockwell	1112
Columbia River, from Young's Bay to John Day's River	do	1–10, 000	1868	do	1123
Columbia River, from Cape Disappointment to Chinook Point	do	1–10, 000	1869	do	1138
Columbia River, from Chinook Point to Gray's Point	do	1–10, 000	1869	do	1139*a*
Columbia River, Sandy Island and Chinook Spit	do	1–10, 000	1869	do	1139*b*
Washington Harbor, Strait of Juan de Fuca	Washington Ter.	1–10, 000	1870	J. S. Lawson	1165
New Dungeness, part of	do	1–10, 000	1870	do	1168
Protection Island to New Dungeness	do	1–10, 000	1870	do	1169
Smith Island	do	1–10, 000	1870	do	1170
Port Madison	do	1–10, 000	1868	do	1087

List of original topographical sheets registered in the archives, &c.—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Register number.
Admiralty Bay, Puget Sound	Washington Ter.	1-10, 000	1868	J. S. Lawson	1164
Shilshole Bay, Admiralty Inlet	....do	1-10, 000	1867	......do	1064
Port Discovery entrance, sheet No. 1	....do		1868-'69	......do	1124
Port Discovery, sheet No. 2	....do		1869	......do	1125
Port Discovery, sheet No. 3	....do		1869-'70	......do	1126

List of hydrographic sheets registered in the archives of the United States Coast Survey from January 1, 1866, to December 31, 1871.

Localities.	State.	Scale.	Date.	Hydrographer.	Register number.
Coast from Mosquito Harbor to Seal Harbor	Maine	1-10, 000	1866	R. E. Halter	907
Quoddy Roads and Johnson's Bay	....do	1-10, 000	1866	H. L. Marindin	895
Western entrance Moose-a-bec Reach	....do	1-10, 000	1870	F. F. Nes	1060
Moose-a-bec Reach	....do	1-10, 000	1870	......do	1059
Indian River	....do	1-10, 000	1870	......do	1061
Winter Harbor and approaches	....do	1-10, 000	1867	H. Anderson	938
Entrance to Isle au Haut Bay	....do	1-20, 000	1870	F. P. Webber	1074
Isle au Haut Bay	....do	1-20, 000	1869	Charles Junken	1028
Hurricane Island Sound and vicinity	....do	1-10, 000	1869	......do	1029
The Basin, on Vinal Haven Island	....do	1-10, 000	1870	F. P. Webber	1075
Fox Island Bay and vicinity	....do	1-10, 000	1870	......do	1073
Fox Islands Thoroughfare, eastern part	....do	1-10, 000	1868	Charles Junken	983
Fox Islands Thoroughfare, western part	....do	1-10, 000	1868	......do	982
Penobscot Bay, approaches to	....do	1-20, 000	'66, '7, '8	......do	1051
Penobscot Bay, entrance to	....do	1-20, 000	1866-'67	......do	943
Penobscot Bay, from Owl's Head to Ensign Island	....do	1-20, 000	1869	F. P. Webber	1086
Penobscot Bay, between Owl's Head and Fox Islands	....do	1-20, 000	1869	Charles Junken	1030
Penobscot Bay, islands south of Islesboro	....do	1-10, 000	1869	F. P. Webber	1087
Camden and Rockport Harbors	....do	1-10, 000	1865	H. Anderson	873
Penobscot River, from Bangor to Hampden	....do	1-10, 000	1867	J. A. Sullivan	934
Muscle Ridge Channel	....do	1-10, 000	1866-'67	R. E. Halter and Ch. Junken.	952
Muscle Ridge Islands	....do	1-10, 000	1867	R. E. Halter	953
Saint George's River Entrance	....do	1-10, 000	1865	R. E. Halter and C. Fendall.	872
Muscongus Bay	....do	1-10, 000	1867	R. E. Halter	950
Muscongus Bay	....do	1-10, 000	1868	......do	986
Meduncook River and Point Pleasant Gut	....do	1-10, 000	1866-'67	......do	951
Medomak River	....do	1-10, 000	1866	H. Anderson	960
Medomak River, from Bremen to Havener's Ledge	....do	1-5, 000	1866	......do	960 *bis.*
John's Bay	....do	1-10, 000	1867	R. E. Halter	920
Damariscotta River, from New Castle Bridge to Clark's Cove	....do	1-10, 000	1866	E. Hergesheimer	903
Sheepscot Bay, between Griffith's Head and Kennebec River	....do	1-10, 000	1868	J. S. Bradford	971
Ebenecook Harbor, Town's End Gut, Back River	....do	1-10, 000	1866	E. Hergesheimer	891
Hell Gate, Back River	....do	1-10, 000	1865	H. Anderson	893
Great and Little Hell Gates and Goose-Rock Passage	....do	1-5, 000	1867	J. S. Bradford	930
Hockomock and Knubble Bays, Sasanoa River	....do	1-10, 000	1867	......do	929
Kennebec River, from Swan Island to Richmond	....do	1-10, 000	1869	C. H. Boyd	1064
Kennebec River, from Richmond to Gardiner	....do	1-10, 000	1870	......do	1065
Vicinity of Cape Small Point	....do	1-10, 000	1868	J. S. Bradford	972
New Meadow River	....do	1-10, 000	1866	J. W. Donn	899
Head of Maquoit, Middle, and Quohog Bays, and Harpswell Sound	....do	1-10, 000	1869	H. Anderson	1008
Off-shore soundings from Seguin Island to Cape Elizabeth	....do	1-40, 000	1867	R. Platt, U. S. N.	933
Portland Harbor	....do	1-5, 000	1867	......do	949
Portland City and Harbor, sheet No. 1	....do	1-1, 200	1868	H. Anderson	1032
Portland City and Harbor, sheets Nos. 2 and 3	....do	1-2, 400	1869	......do	1033 *a, b*
Portland City and Harbor, sheets Nos. 4 and 5	....do	1-2, 400	1869	......do	1034 *a, b*
Saco River	....do	1-5, 000	1866	G. Davidson	882
Saco River, from Saco to Chandler's Point	....do	1-5, 000	1867	F. F. Nes	941
Saco River, up to Chandler's Point	....do	1-5, 000	1867	......do	942
Coast of New Hampshire, from Pulpit Rock to Great Boar's Head.	New Hampshire	1-10, 000	1870	H. Anderson	1068
Coast of New Hampshire, from Great Boar's Head to Salisbury	....do	1-10, 000	1870	......do	1069

List of hydrographic sheets registered in the archives, &c.—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Register number.
Town, Fore and Back Rivers, Weymouth	Massachusetts	1-10, 000	1869	J. S. Bradford	1021
Duxbury Bay	...do	1-10, 000	1867, '70	H. Anderson	1035
Plymouth Harbor	...do	1-10, 000	1870	......do	1067
Monomay Shoals, reconnaissance	...do	1-10, 000	1868	F. F. Nes	961
Vineyard Haven Harbor	...do	1-10, 000	1871	H. Mitchell	1106
Mitchell's Falls, Merrimack River	...do	200 ft. to 1 in.	1867	......do	1012
Narragansett Bay, from Quonset Point to Dutch Island	Rhode Island	1-10, 000	1868	F. P. Webber	992
Narragansett Bay, from Hope Island to Patience Island	...do	1-10, 000	1867-'68	......do	939
Greenwich Bay	...do	1-5, 000	1867	......do	940
Narragansett Bay, head of, and Providence River	...do	1-10, 000	1865, '67	......do	880
Providence River, from city of Providence to Stargut Island	...do	1-5, 000	1865	......do	878
Warren River	...do	1-5, 000	1865	......do	888
Thames River, near New London	Connecticut	1-1, 200	1869	Charles Junkin	1006
Frying Pan and Pot Rock	New York	1-1, 280	1866	W. S. Edwards	896
Wallabout Bay	... do	1-1, 250	1869	F. F. Nes	1065
Off the Battery	...do	1-2, 500	1867	W S. Edwards	910
New York Bay, between Governor's Island and Robbin's Reef	...do	1-10, 000	1868	F. H. Gerdes	970
Swash Channel, examination of	...do	1-20, 000	1866	W. S. Edwards	897
Main channel between Sandy Hook and Flynn's Knoll and Scotland Shoal.	...do	1-20, 000	1869	F. F. Nes	1011
Rondout Harbor, from entrance to Sleight's Ferry	...do	1-2, 500	1868	F. H. Gerdes and F. F. Nes.	979
Rondout Harbor, from Sleight's Ferry to entrance of Delaware and Hudson Canal.	...do	1-1, 250	1868	......do	978
Lake Champlain, from Cumberland Head to Valcour Island	...do	1-20, 000	1870	Charles Junken	1058
Burlington Harbor	Vermont	1-10, 000	1871	F. D. Granger	1105
Barnegat Inlet	New Jersey	1-10, 000	1866	C. Fendall	883
Delaware River, from Ridley's Creek to Walsh Street Wharf	Pennsylvania	1-1, 200	1870	Charles Junken	1057*a*
Delaware River, from Walsh Street Wharf to Carson's Wharf	...do	1-1, 200	1870	......do	1057*b*
Susquehanna River, mouth of	Maryland	1-10, 000	1867	F. P. Webber	898
Sassafras River	...do	1-10, 000	1870	W. W. Harding	1071
Romney, Farley's, Stillpond, Churn, and Lloyd's Creeks	...do	1-10, 000	1870	......do	1072
Chester River, No. 1, and Morgan's Creek	...do	1-5, 000	1869-'70	......do	1026*a*, *b*
Chester River, No. 2	...do	1-5, 000	1869-'70	......do	1027
Langford Creek	...do	1-10, 000	1870	......do	1078
Patapsco River, mouth of	...do	1-20, 000	1866	F. P. Webber	913
Patapsco River, Brewster's Channel	...do	1-10, 000	1866	......do	914
Patapsco River, Brewster's Channel, enlarged from No. 913	...do	1-10, 000	1866	......do	915
Patapsco Piver, creeks emptying into	...do	1-20, 000	1869	J. W. Donn	1007
Tributaries of Severn and South Rivers	...do	1-20, 000	1870-'71	W. W. Harding	1077*a*
Head of Severn River	...do	1-20, 000	1870	......do	1077*b*
Tributaries of Wye River	...do	1-10, 000	1870	......do	1050*a*
Tributaries of Saint Michael's River	...do	1-10, 000	1870	......do	1050*b*
Heads of Harris, Broad, and Porter's Creeks	...do	1-10 000	1870	......do	1049*b*
Tributaries of Tredhaven Creek	...do	1-10, 000	1870	......do	1049*a*
Choptank River, from Wing's Landing to Denton	... do	1-10, 000	1870	......do	1048
Potomac River, from Analostan Island to Long Bridge	District Columbia.	1-5, 000	1867	C. Fendall	1082
Wicomico River, Saint Clement's and Breton's Bay	Maryland	1-20, 000	1860, '68	W. T. Muse, U. S. N., and J. W. Donn.	969
Nomini Bay, Lower Machodoc and Mattox Creeks	Virginia	1-20, 000	1868	J. W. Donn	967
Yeocomico and Coan Creeks	...do	1-20, 000	1868	......do	968
Smith's, Goose, and Fox Islands, Tangier Sound	...do	1-20, 000	1869	W. W. Harding	997
Little Annemessex River	...do	1-10, 000	1868-'69	......do	985
Pocomoke Sound, creeks from Messongo Creek to Onancock Creek.	...do	1-20, 000	1869	......do	993
Pocomoke River Entrance	...do	1-10, 000	1869	......do	1004
Pocomoke River, sheets Nos. 1 and 2	...do	1-5, 000	1869	......do	1022*a*, *b*
Pocomoke River, sheets Nos. 3 and 4	...do	1-5, 000	1869	......do	1023*a*, *b*
Pocomoke River, sheets Nos. 5, 6, and 7	...do	1-5, 000	1869	......do	1024*a*, *b*, *c*
Occohannock, Craddock, and Nandua Creeks	...do	1-20, 000	1868	C. Fendall	976*a*
Naswaddox Creek	...do	1-20, 000	1868	......do	976*b*
Hunger's Creek	...do	1-20, 000	1868	......do	976*c*
Great Wicomico River	...do	1-20, 000	1869	J. W. Donn	1003
Little Bay, Nantepoison, Tapp's, Dimer's, Indian, Dividing, and Mill Creeks.	...do	1-20, 000	1869	......do	1005

List of hydrographic sheets registered in the archives, &c.—Continued.

Localities.	State.	Scale.	Date.	Hyorgrapher.	Register number.
Estuaries of the Corrotoman River	Virginia	1–10, 000	1869	J. W. Donn	1002
Estuaries of the Rappahannock River	do	1–20, 000	1869	do	1001
Bowler's and Corner Rock, Rappahannock River	do	1–2, 500	1867	do	937
Piankatank River	do	1–20, 000	1869	do	988
Milford Haven, (also topography)	do	1–20, 000	1868–'69	do	987
Estuaries of Mobjack Bay	do	1–20, 000	1868	do	984
Back and Pocosen Rivers	do	1–20, 000	1868	C. Fendall and W. W. Harding.	977
Magothy Bay	do	1–20, 000	1869	W. W. Harding	1013
Broadwater, from Ship Shoal Inlet to Sand Shoal Inlet	do	1–20, 000	1870	do	1070*a*
Broadwater, from Sand Shoal Inlet to Hog Island Inlet	do	1–20, 000	1870	do	1070*b*
Broadwater, Great Machipongo River, and branches	do	1–20, 000	1871	J. W. Donn	1103
Little Machipongo, to head of Broadwater	do	1–20, 000	1871	do	1104
Newport News Point	do	1–10, 000	1865	E. Hergesheimer	877
Elizabeth River, from Washington Point to navy-yard	do	1–2, 500	1866	R. Platt, U. S. N.	894
Off-shore soundings from Sheephouse Hill to Killdevil Hills	Virginia and North Carolina.	1–40, 000	1868	do	965
Off-shore from Killdevil Hills to Loggerhead Inlet	North Carolina	1–40, 000	1870	do	1053
Off-shore soundings from Loggerhead Inlet to Cape Hatteras	do	1–40, 000	1869–'70	do	1056
Off-shore soundings from Cape Hatteras to Federal Point	do	1–240, 000	1865–'66	do	884
Lookout Shoals	do	1–40, 000	1865–'66	R. Platt and C. Junken.	885
Long Shoal, Pamplico Sound, reconnaissance of	do	1–10, 000	1866	J. S. Bradford	887
Pamplico Sound, from Royal Shoal to Brant Island	do	1–40, 000	1866, '69, 1870	J. S. Bradford and F. F. Nes.	1083
Pamplico Sound, western part	do	1–20, 000	1869	F. F. Nes	1010
Bay River	do	1–20, 000	1869	do	1009
Pamplico River, from Pamplico light-house to Indian Island	do	1–20, 000	1869	do	1088
Pamplico River, from Adams Point to Rumley Marshes	do	1–20, 000	1868, '71	R. E. Halter and F. D. Granger.	1099
Pamplico River, from Rumley Marshes to Ragged Point	do	1–20, 000	1871	F. F. Nes	1100
Pamplico River, from Ragged Point to city of Washington	do	1–20, 000	1871	do	1101
Cedar Island, bay, and vicinity	do	1–20, 000	1870	do	1079
Neuse River, from Point of Marsh to Cedar Point	do	1–20, 000	1868	J. S. Bradford and F. F. Nes.	974
Neuse River, from Cedar Point to Wilkinson's Point	do	1–20, 000	1868	J. S. Bradford	963
Neuse River, from Cherry Point to Johnson's Point	do	1–20, 000	1867–'68	do	956
Neuse River, from Johnson's Point to Fort Anderson	do	1–10, 000	1866	do	892
South River, Turnagain Bay, and other tributaries to Neuse River.	do	1–20, 000	1868–'69	J. S. Bradford and F. F. Nes.	975
Entrance to Cape Fear River, the bars of Oak Island, and Bald Head Channel.	do	1–5, 000	1871	Charles Junken	1089
Entrance to Cape Fear River	do	1–10, 000	1865	J. S. Bradford	870
Entrance to Cape Fear River, New Inlet	do	1–10, 000	1865	do	875
Cape Fear River, between Forts Caswell and Johnson	do	1–10, 000	1866	do	876
Cape Fear River, inner bar	do	1–10, 000	1870	F. F. Nes	1014
Main Channel over Charleston Bar	South Carolina	1–20, 000	1869	R. E. Halter	981
Charleston Bar	do	1–20, 000	1865	C. O. Boutelle	874
Charleston Harbor	do	1–10, 000	1865	do	881
Bull and Combahee Rivers	do	1–10, 000	1871	Charles Hosmer	1084
Broad River	do	1–10, 000	1865	R. E. Halter	869
Jericho, Chowan, and Ballast Creeks, tributaries of Beaufort River.	do	1–10, 000	1868	Charles Hosmer	962
Off-shore soundings from Port Royal Entrance to Wassaw Sound, Gaskin and Joiner's Banks.	South Carolina and Georgia.	1–40, 000	1866	C. O. Boutelle	966
Savannah River Entrance	Georgia	1–20, 000	1866	do	944
Savannah River, from Tybee Light to Elba Island	do	1–10, 000	1866	do	945
Savannah River, from Elba Island to Fig Island	do	1–10, 000	1865–'66	do	946
Savannah River, city front	do	1–5, 000	1865–'66	do	947
Entrance to Wassaw Sound	do	1–20, 000	1864, '66	do	904
Saint Catharine's Sound and estuaries	do	1–20, 000	1867	Charles Junken	916
Saint Catharine's Entrance	do	1–20, 000	1867	do	928
Inland passages between Sapelo and Doboy Sounds	do	1–10, 000	1868	do	959
Doboy Inlet and approaches	do	1–20, 000	1868	do	957
Doboy Sound, with Darien and North River, and adjacent creeks.	do	1–10, 000	1868	do	964
Saint Andrew's and Jekyl Sounds	do	1–20, 000	1870	R. E. Halter	1020
Coast from Saint Andrew's Bar to Saint Mary's Bar	do	1–20, 000	1870	Charles Junken	1062

List of hydrographic sheets registered in the archives, &c.—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Register number.
Florida Passage, from Saint Andrew's Sound to Cumberland Island.	Georgia	1-20, 000	1870	Ch. Junken	1063
Main ship-channel over Saint Mary's River Bar	Florida	1-20, 000	1869	R. E. Halter	980
Saint Augustine and vicinity	do	1-10, 000	1870	H. Anderson	1036
North and Guano Rivers	do	1-10, 000	1870	do	1046
Matanzas River	do	1-10, 000	1870	do	1047
Off-shore soundings from Sombrero to Sand Keys	do	1-160, 000	1868	Rob. Platt, U. S. N.	1066
Off-shore soundings, Straits of Florida westward	do	1-400, 000	1869	do	1090
Off-shore soundings, Straits of Florida eastward	do	1-400, 000	1869	do	1091
Off-shore soundings from Key West to Charlotte Harbor	do	1-400, 000	1867	do	911
Off-shore soundings from Sand Key to Marquesas Keys	do	1-40, 000	1867	do	912
Off-shore soundings from Marquesas Keys to Rebecca Shoals	do	1-40, 000	1870	do	1052
Off-shore soundings, approaches to Dry Tortugas Keys	do	1-40, 000	1867-'68	do	955
Florida Reefs, from Marquesas to Dry Tortugas Keys	do	1-80, 000	1867-'68	do	954
Florida Reefs, western end Marquesas to Dry Tortugas Keys	do	1-80, 000	1871	do	1076
El Moro to Playa de Marianao, north coast of Cuba	Cuba	1-10, 000	1867	W. S. Edwards	900
San Carlos Bay and Caloosa Entrance	Florida	1-20, 000	1866, '67	do	917
Pine Island Sound, part of, and approaches to the Caloosahatchee.	do	1-20, 000	1866	C. T. Iardella	908
Cedar Keys, main channel	do	1-10, 000	1871	F. P. Webber	1080
Saint George's Sound	do	1-20, 000	1871	H. Anderson	1092
Santa Rosa Sound, the Narrows, and west end of Choctawhachee Bay.	do	1-20, 000	1871	H. G. Ogden	1107
Santa Rosa Sound, from Deer Point to Long Pritchard Point	do	1-20, 000	1871	do	1108
The Rigolets	Louisiana	1-20, 000	1870	F. P. Webber	1054
Lake Borgne	do	1-40, 000	1870	do	1055*a*
Eastern part of Lake Pontchartrain	do	1-40, 000	1870	do	1055*b*
Isle au Breton Bay	do	1-40, 000	1869	do	999
Isle au Breton Sound, southeast part	do	1-40, 000	1869	do	1000
Passe à Loutre and Southeast Pass	do	1-20, 000	1867	F. H. Gerdes	989
Passe à Loutre and Bar	do	1-10, 000	1867	do	927
Northeast and Southeast Passes	do	1-10, 000	1867	do	926
West, East, and Garden Island Bays	do	1-40, 000	1868	F. P Webber	991
South Pass	do	1-20, 000	1867	F. H. Gerdes	990
South Pass Bar	do	1-10, 000	1867	do	925
Southwest Pass	do	1-20, 000	1867	do	923
Southwest Pass and Bar	do	1-10, 000	1867	do	924
Mississippi River, part of	do	1-10, 000	1866	do	922
Mississippi River, from Grand Prairie to Bohemia	do	1-20, 000	1871	C. H. Boyd	1093
Galveston Entrance and Bar	Texas	1-10, 000	1867	F. F. Nes	906
Galveston Bay, resurvey	do	1-20, 000	1867	do	918
Galveston Bay, resurvey	do	1-10, 000	1867	C. H. Boyd	919
Galveston Harbor, comparative chart showing changes from 1851 to 1867.	do	1-10 000	1867	do	919*bis*
Galveston Bay, western entrance	do	1-20, 000	1867	F. F. Nes	931
West Galveston Bay	do	1-20, 000	1867	do	932
Matagorda Bay, part of	do	1-20, 000	1866, '71	F. P. Webber and F. D. Granger.	1031
Trespalacios and Turtle Bays	do	1-20, 000	1871	F. D. Granger	1094
Carancahua Bay	do	1-20, 000	1871	do	1095
Pass Cavallo	do	1-20, 000	1871	do	1097
Lavaca Bay and vicinity	do	1-20, 000	1871	do	1098
Espiritu Santo Bay	do	1-20, 000	1871	do	1096
Aransas Pass	do	1-10, 000	1868	F. F. Nes	996
Aransas Bay	do	1-20, 000	1869	H. Anderson	995
Corpus Christi Pass	do	1-10, 000	1869	do	994
Corpus Christi Bay	do	1-20, 000	1868	F. F. Nes	958
Entrance to Brazos Santiago and Laguna Madre	do	1-20, 000	1867	C. H. Boyd	909
Santa Barbara Channel, in-shore sounding, No. 1	California	1-10, 000	1869	E. Cordell and G. Farquhar.	1038
Santa Barbara Channel, in-shore sounding, No. 2	do	1-10, 000	1869	do	1039
Santa Barbara Channel, in-shore sounding, No. 3	do	1-10, 000	1869	do	1040
Santa Barbara Channel, in-shore sounding, No. 4	do	1-10, 000	1869	do	1041
Santa Barbara Channel, in-shore sounding, No. 5	do	1-10, 000	1869	do	1042
Santa Barbara Channel, in-shore sounding, No. 6	do	1-10, 000	1869	do	1043

List of hydrographic sheets registered in the archives, &c.—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Register Number.
Santa Barbara Channel, in-shore sounding, No. 7	California	1-10, 000	1869	E. Cordell and G. Farquhar.	1044
Santa Barbara Channel, off-shore soundings	....do	1-100, 000	1869	......do	1045
Santa Barbara Channel, entrance Coxo anchorage	....do	1-10, 000	1869	......do	1037
Roadstead under Point Sal	....do	1-5, 000	1867	E. Cordell	921
Harbor of Buenaventura	....do	1-10, 000	1870	W. E. Greenwell	1061
Off-shore soundings, Point Pedro, Santa Cruz	....do	1-100, 000	1865	E. Cordell	871
Suisun Bay, Cordelia, Suisun, and Montezuma Creeks	....do	1-20, 000	1867	......do	948
Suisun Bay, with confluence of Sacramento and San Joaquin Rivers.	....do	1-20, 000	1866-'67	......do	905
Sacramento and San Joaquin Rivers	....do	1-10, 000	1867	......do	935
Carquines Straits, part of	....do	1-10, 000	1866	......do	879
Off-shore soundings from Point Reyes to Bodega Head	....do	1-100, 000	1866	......do	889
Off-shore soundings from Point Reyes to Tomales Point	....do	1-20, 000	1866	......do	890
Crescent City Reef	....do	1-20, 000	1869	A. W. Chase	1025
Coose Bay	Oregon	1-10, 000	1865	J. S. Lawson	901
Coose Bay	....do	1-10, 000	1865	......do	902
Yaquina Bay	....do	1-10, 000	1868	A. W. Chase	998
Nehalem River Entrance	....do	1-5, 000	1868	E. Cordell and G. Farquhar.	973
Tillamook Bay	....do	1-10, 000	1866-'67	J. Kincheloe	936
Columbia River, from Three Tree Point to Gray's Bay	....do	1-10, 000	1867-'68	E. Cordell	1015
Columbia River, from Cathlamet Head to Settler's Point	....do	1-10, 000	1868	......do	1016
Columbia River, from Settler's Point to Tongue Point	....do	1-10, 000	1868	......do	1017
Columbia River, from Tongue Point to Cape Disappointment	....do	1-20, 000	1868	......do	1018
Columbia River Entrance	....do	1-20, 000	1868	......do	1019
Destruction Island and vicinity	Washington Ter.	1-10, 000	1866	J. S. Lawson	886
Port Madison	....do	1-10, 000	1868	......do	1102

APPENDIX No. 6.

REPORT OF METEOROLOGICAL EFFECTS ON TIDES, FROM OBSERVATIONS BY PROF. WM. FERREL.

CAMBRIDGE, MASS., *May* 31, 1873.

DEAR SIR: I have the honor to submit the following final report on the discussions of the tidal observations of Boston Harbor, pertaining to the meteorological effects of the winds and the changes of barometric pressure upon the heights of the tides. The heights of high and low waters for six years, from 1856 to 1861, inclusive, were computed by the formulas and tables given in a previous report and the results compared with the tidal observations and the residuals noted. From the manuscript-records of the observatory of Harvard College, which were permitted by the director to be used for the purpose, the corresponding barometric pressures and forces and directions of the wind were obtained and collated with the residuals. The range of the barometer was then divided into seven parts, and all the pressures belonging to each one of these divisions were grouped together, and also the corresponding residuals belonging to both the high and the low waters, and the averages of the residuals compared with those of the barometric pressures. The observations when the barometer was rising were kept separate from those when it was falling, in order to determine whether there is any sensible difference on account of the inertia or the friction of the water preventing it from assuming at each instant the condition of static equilibrium. The following results were obtained

	Rising barometer.			Falling barometer.			Averages.		
	No. of obs.	Barometric pressure.	Tidal residuals.	No. of obs.	Barometric pressure.	Tidal residuals.	No. of obs.	Barometric pressure.	Tidal residuals.
		Inches.	*Feet.*		*Inches.*	*Feet.*		*Inches.*	*Feet.*
	92	29.505	+0.250	171	29.475	+0.245	263	29.493	+0.248
	180	29.710	0.110	319	29.720	0.180	499	29.715	0.221
	225	29.845	+0.035	280	29.840	+0.050	505	29.843	+0.043
High waters.....	313	29.940	−0.100	336	29.935	−0.010	649	29.938	−0.055
	457	30.050	0.130	408	30.050	0.080	865	30.050	0.107
	480	30.195	0.165	402	30.190	0.190	882	30.197	0.193
	305	30.415	−0.330	214	30.410	−0.320	519	30.417	−0.326
	66	29.495	+0.395	108	29.485	+0 395	174	29.488	+0.395
	183	29.705	0.195	250	29.714	0.245	433	29.710	0.147
	224	29.840	0.065	239	29.845	0.115	463	29.843	0.085
Low waters.....	349	29.945	0.040	359	29.945	0.080	708	29.945	0.060
	430	30.055	+0.005	412	30.050	+0.010	842	29.053	+0.008
	482	30.200	−0.065	443	30.190	−0.060	925	30.195	−0.063
	323	30.425	−0.190	258	30.420	−0.165	581	30.423	−0.178
	158	29.502	+0.307	279	29.480	+0.320	437	29.491	+0.316
	363	29.708	0.152	569	29.717	0.212	932	29.712	0.184
	449	29.842	0.050	519	29.843	0.082	968	29.842	0.064
Averages	662	29.943	−0.030	695	29.940	+0.035	1,357	29.942	+0.003
	887	30.053	0.062	820	30.050	−0.035	1,707	30.052	−0.049
	962	30.197	0.115	845	30.190	0.125	1,807	30.194	0.124
	628	30.422	−0.260	472	30.415	−0.242	1,100	30.419	−0.251

If the tables from which the heights of the tides were computed were correct, the algebraic sum of all the tidal residuals in the last column of the preceding table for the high waters, and likewise for the low waters, should be 0. The average of the former for the seven groups of observations, giving each equal weight, is −0.024 feet, and that of the latter, 0.065 feet. This indicates an error, −0.020 feet for the mean level, and of 0.044 feet for the mean amplitude, of the

tide from the tables. The former may be regarded as falling within the limits of the errors of observation in a series of six years only, or it may be due to a small change of the zero of the tide-gauge during the full series. The discrepancy in the amplitude, being about a half-inch, cannot be regarded as falling within the limits of the errors of observation, and must be due, at least in part, to a small error in the tables.

The average atmospheric pressure at the observatory, as deduced from all the observations, is 30.007 inches. If we, therefore, put p for this pressure at any time expressed in inches, we have, for the expression of the correction of the heights of the tide due to changes in the barometer, $(30^{\text{in}}.007-p)$ C, in which C is a constant, to be determined from observation. This expression put equal to each of the tidal residuals expressed in inches in the lower right-hand column of averages in the preceding table, using the corresponding values of barometric pressure for the values of p, we get seven equations for determining the most probable value of C. Giving the equations weight according to the number of observations, we thus get—

$$C=7.33 \pm 0.05$$

The theoretical value of this constant is 13.56, this being the ratio between the densities of water and mercury. I am unable to explain why its value in Boston Harbor is little more than half as much. The value of this constant also, as determined from observation for several other ports, is much greater. M. Daussy found that at Brest the ocean rises 0.223 of a meter for a depression of 0.0158 of a meter in the mercury, (*Connaissance du temps*, 1834.) This gives 14.11 for the value of the constant at that port, which is a little greater than the theoretical value. Lubbock obtained 11.1 for the value of this constant at Liverpool; but at London he found that the water rises 6.3 inches for a depression of 0.90 of an inch of the mercury, (*Phil. Trans.*, 1836, p. 121.) This gives only 7.0 for the value of the constant at London, which is less than the value obtained for Boston Harbor. The value of this constant, then, seems to differ very much for some reason in different ports.

By comparing the tidal residuals of rising barometer with those of falling barometer at the bottom of the preceding table of results, it is seen that there is a perceptible difference near mean barometer, and that the sea-level is a little lower when the barometer is at the mean and rising than it is when the barometer is at the mean and falling. It was overlooked in my preliminary report, which has been published in Silliman's Journal, that this difference is exactly contrary to what we would suppose it would be, and seems to indicate that the changes of sea-level anticipate the forces upon which they depend. When the barometer is rising, the sea-level is falling; and when the former has arrived at the mean, the latter, if the changes are retarded by inertia or friction, should be still a little above the mean, whereas the residuals in the preceding table, whether we consider those belonging to high and low waters separately, or the averages of the two, clearly indicate that the sea-level is already below the mean. And almost every individual result belonging to the different groups of observations gives the same result. We cannot, therefore, suppose that it may be an accidental result falling within the limits of the possible errors of observation. I think it may be satisfactorily explained in this way: When the barometer is rising, we usually have clearing-off weather, with west or southwest winds, which tend to lower the sea-level, and consequently they more than counteract the effect of inertia or of friction, if these latter effects are at all sensible; when the barometer is falling, we usually have east winds, or at least an absence of west winds, and hence the sea-level at this time is a little above the mean level from this cause.

In order to obtain the effect of the winds from the different points of the compass upon the heights of the tides, all the tidal residuals for the six years belonging to the winds from each of the eight principal points of the compass were grouped together, and the averages taken, and also the corresponding average forces of the winds and of the barometric pressures. The forces of the winds in the record of the observations were denoted by the numbers 0, 1, 2, 3, and 4; 0 denoting a calm and 4 the strongest winds recorded.

The following results were thus obtained:

Wind.	No. of observations.	Barometric pressure.	Average force of wind.	Average tidal residuals.	Corrected residuals.
		Inches.		*Feet.*	*Feet.*
N.	244	30.007+.005	1.6	+0.21	+0.21
N. E.	317	+.009	1.7	+0.23	+0.24
E.	274	+.055	1.3	+0.04	+0.07
S. E.	131	+.053	1.5	+0.02	+0.05
S.	165	−.074	1.8	−0.03	−0.07
S. W.	796	−.021	1.5	−0.10	−0.11
W.	677	−.073	1.6	−0.18	−0.22
N. W.	527	+.001	1.6	−0.10	−0.11
Calm.	946	+.051	0.0	−0.01	+0.02

The number of observations in the second column denotes the relative frequency of the winds from the several different points of the compass. From the column of barometric pressures it is seen that with winds from NW. around by N. to SE. the barometer stands *above* the mean, but that with winds from SE. around by S. to NW. the barometer stands *below* the mean. The average tidal residuals follow very nearly the same law. The full effect of the wind, therefore, is not shown by the fifth column, since the tidal residuals are always affected by a corresponding change in the barometer, and require to be corrected by the preceding expression of the correction with the value of the constant C as determined. The last column, containing the residuals thus corrected, indicates the effect of a wind from each of the several points of the compass having the average force of the wind from that point.

It is pretty generally thought that the winds cause very considerable changes of sea-level, but it is seen from the last column of the table above that an average NE. wind raises the sea-level only about three inches, and that a SW. wind depresses it not quite so much. If the numbers in the scale of forces represent the velocities of the winds, the elevating and depressing effect of the winds may not be proportional to the forces, so that a strong wind denoted by 4 in the scale may raise or depress the sea-level three or four times as much as a wind of average force, this depending upon the law of friction between the wind and the water. Very strong winds, therefore, may change the sea-level in Boston Harbor a foot or more; and this agrees well with individual observations. Of about 700 tidal residuals of high water throughout the year 1859, obtained from a comparison of computation by the formulas and tables with observations, only ten amount to as much as one foot. If, therefore, we suppose that these residuals are due to the effects of the winds only, and no part of them to other disturbing causes, and to errors of the tidal formulas and tables, even upon this supposition we know by actual measurements with the tide-gauge that in the course of a whole year, the sea-level of Boston Harbor is not often changed by the winds as much as one foot.

An important meteorological result is shown in the fourth column of the preceding table, which is that the barometer during calms stands very near the maximum of all the averages of the winds from the different quarters. This indicates that the winds are generally of a cyclonic character, prevailing mostly in the interior of the cyclones where there is barometric depression, and that the calms are mostly in the external part where there is high barometer.

The following table of results brought out in the discussion shows the annual changes of the barometer. As the unreduced observations were used, a correction for temperature in this case has to be applied, to reduce the barometer to the mean of the year to correspond with the preceding results, in which the average corresponds to the mean temperature of the year, or to reduce them, as usual, to the temperature of freezing.

In the following table the reduction is to freezing and for capillarity:

Month.	Number of observations.	Barometer.	Reduced to 32° and for capillarity.	Corrected barometer.
		Inches.	*Inches.*	*Inches.*
January	324	29.995	−0.004	29.934 + .057
February	310	30.007	0.020	+ .053
March	363	29.886	0.043	− .091
April	347	29.957	0.066	− .043
May	354	30.013	0.090	− .011
June..........	361	29.961	0.110	− .083
July	354	30.021	0.121	− .035
August	377	30.023	0.119	− .030
September	360	30.104	0.104	+ .066
October.......	358	30.058	0.076	+ .048
November	335	29.947	0.046	+ .067
December.....	320	30.055	−0.020	+ .001

The mean barometer at the height of 71 feet above mean sea-level, and reduced to the temperature of 32°, is 29.934 inches. Adding 0.082 inch for the reduction to mean sea-level, we get 30.016 inches for the mean height of the barometer at mean sea-level in Boston Harbor.

The last column in the table shows that there is a very small inequality, with an annual argument, and a co-efficent of about 0.05 inch, making the barometric pressure a minimum about May and a maximum in November. The number of observations was not sufficient to eliminate the accidental irregularities, and to determine this small annual inequality very accurately; but it is evidently too small to account for much of the observed annual inequality in the mean sea-level.

The following table of results is obtained from classifying the observations of the winds according to their directions for each of the four seasons and for the whole year:

Season.	N.		N. E.		E.		S. E.		S.		S. W.		W.		N. W.	
	Obs.	S. F.	Obs.	S. F.	Obs.	S. F.	Obs.	S. F.	Obs.	S. F.	Obs.	S. F.	Obs.	S. F.	Obs.	S. F.
Winter................	92	153	51	75	22	37	23	36	36	68	189	288	221	378	193	337
Spring	68	117	120	183	106	137	45	63	57	109	183	293	181	323	113	210
Summer...............	34	52	85	149	101	143	37	61	50	67	269	416	150	238	104	176
Autumn...............	60	97	73	129	51	82	31	48	43	75	188	309	167	275	156	264
Whole year......	254	419	329	536	280	399	329	208	186	319	829	1,306	719	1,214	566	987

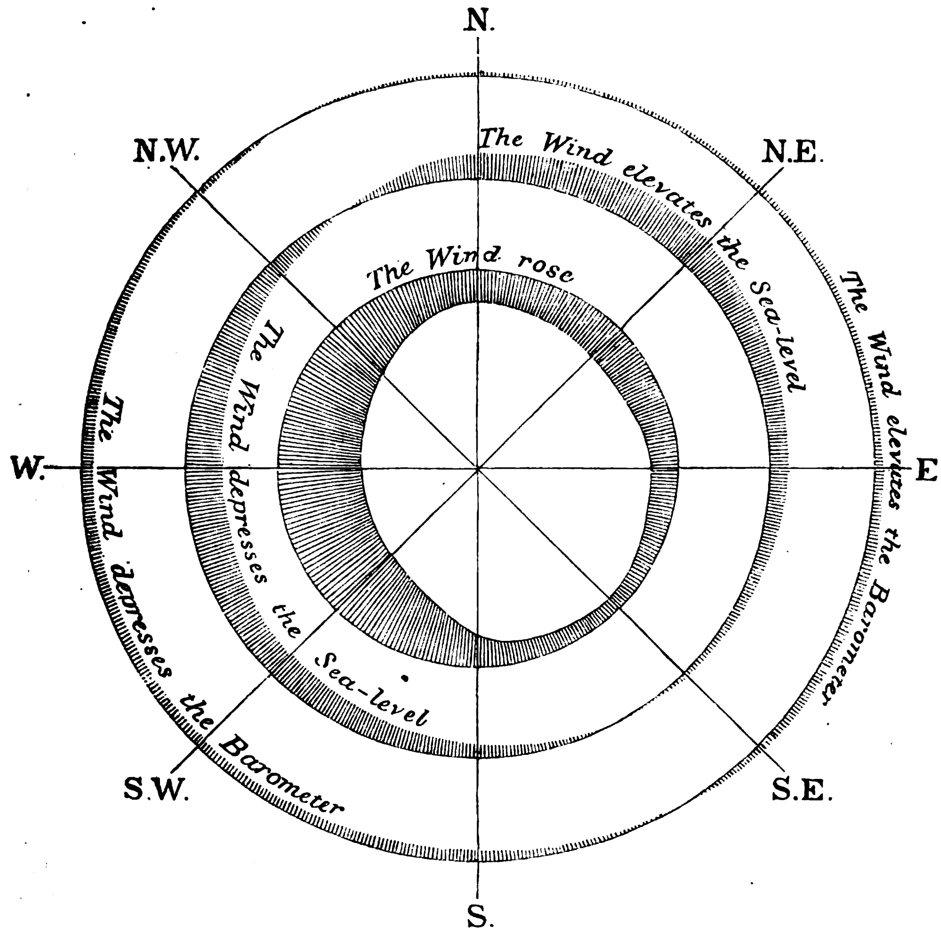
The number of observations denotes, also, the relative frequency of the winds from the different points of the compass. It is seen that the predominating winds are from W. and SW. during all seasons of the year. The numbers headed S. F. are the sums of the numbers in the observations denoting the forces of the wind. There is some uncertainty with regard to the scale used by Professor Bond in denoting the forces, but it is supposed to be the scale from 0 to 6, in which 0 denotes a calm and 6 a velocity of eighty-five miles per hour, the numbers representing the forces being very nearly proportional to the velocities. At any rate, the sums of the forces above may be regarded as representing the relative sums of the distances passed over within the limits of the errors of such observations. With a table of latitude and departure, therefore, we readily determine the relative distances passed over and the directions for each season of the year and for the whole year. We thus get the following table of directions from which the wind blows, and the relative distances traveled over:

Winter.......	N. 78° W.	726
Spring........	N. 85 W.	386
Summer......	S. 71 W.	383
Autumn	N. 84 W.	498
Whole year ..	N. 87 W.	1,920

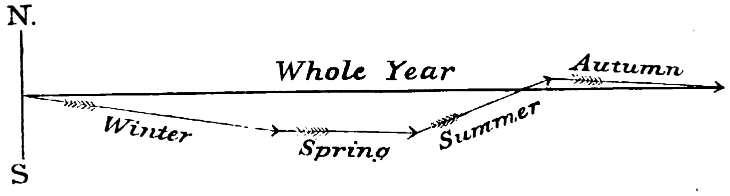
It is seen that during the winter the wind blows from a point on the average 12° N. of W., but

in the summer from a point 19° S. of W. This difference is caused by the difference in the relative temperatures of the land and sea in the two seasons, and shows that the winds have slightly a monsoon character. During the spring and fall, when the relative temperatures are about the same, the winds blow very nearly from the same point, which nearly corresponds with that of the resultant of the whole year, the direction of which is from a point 3° N. of W. The atmosphere in the course of the whole year moves a little more south than north. Dividing 1,920 by 3,299, the whole number of observations, we get 0.58 for the average force in the direction of the resultant. This, by the supposed scale used, corresponds to a velocity of about eight miles per hour, in a direction a little south of east.

The accompanying sketch contains a graphic representation of the relative amounts of wind or distances traveled over, from the different points of the compass during the course of the year, and



Graphic representation of the relative amounts and directions of the wind for each of the four seasons for the whole year at Boston.



of the effects of the winds upon the sea-level and the height of the barometer. The ordinates in the inner circle, determined for the eight principal points only, represent the relative amounts of wind during the year and not the average force of the wind, the center of the circle being in the direction in which the wind blows. The ordinates upon the circumference of the middle circle

represent the effect of the average force of the wind from the different points of the compass upon the sea-level, the ordinates within the circumference denoting depression of the sea-level, and those on the outside of it denoting elevation of sea-level. The scale is one foot to the inch. The effect of the winds upon the barometer, if it is an effect, and the winds and the changes of barometer do not belong to some common cause, is indicated by the ordinates upon the circumference of the outer circle. These ordinates represent the absolute amount of change in the height of the mercurial column.

It also contains a representation of the relative amounts and of the directions of the wind for each of the four seasons and for the whole year. It is readily seen from this that the resultants are mostly in an easterly direction, and that the motion east during the winter is nearly twice as much as it is during the summer. The effect of the east winds upon the resultant for the spring-season is also seen.

Sketch No. 38 contains a graphic representation of the heights of the tides and of the lunitidal intervals given by the tables and by observations, and of the effects of the winds and changes of atmospheric pressure, for the month of July, 1858. This is the time when the obliquity of the moon's orbit to the equator is greater than in any other part of the whole series, and, consequently, when the diurnal tide is the greatest. This causes the alternate heights of high and low waters to be greater and less, as represented in the sketch, near the times of the greatest declinations of the moon, the maximum of the lunar and principal part of this effect occurring two days after the greatest declination. At this time, also, the moon's perigee occurs near the time of one syzigy and its apogee near the time of the other. Hence the predominating influence of the lunar parallactic inequality over that of the solar, or half-monthly, is well represented by the sketch. At the time of the new moon and the moon's perigee these two inequalities combine and make the tides unusually large, but at the time of full moon and the moon's apogee the parallactic inequality more than counteracts the half-monthly inequality, so that when in European ports there is a second maximum, though smaller, in Boston Harbor this second maximum is entirely destroyed by the predominating effect of the lunar parallactic inequality, and the magnitude of the tides do not come up to the mean tide.

The angular points in the sketch represent computation, and the dots observation uncorrected for the effects of meteorological changes. After correcting the observations for variations of barometric pressure by the formula which has been given with the value of the constant C, as determined from observation, and also for the effects of the winds as determined in the preceding discussion, the observations thus corrected are represented by the dash. In general, this correction of the observations improves the agreement with theory, but it sometimes happens that it is the reverse. Of course, this correction for the meteorological effects is only partial and very imperfect. While, perhaps, the principal effects depend upon the local state of the barometer and of the winds, yet a very great part, no doubt, depends upon the meteorological conditions in distant parts of the ocean; for if the barometer and the winds in Boston Harbor, and for a considerable distance around, were to remain the same, yet the meteorological changes in distant parts of the ocean would still cause considerable changes in the sea-level, as well as other oscillations, independent of any astronomical forces. The corrected residuals, represented by the spaces between the angular points and the dashes, depend upon the imperfection of the corrections for the meteorological effects, upon errors of the tables, and of theory. It is not claimed, of course, that the theory is perfect, and the tables do not represent accurately the theory. To attempt to represent accurately the theory would require very complex formulas and tables, which would increase very much the labor of computing the tides; and since no accurate comparisons can be made between theory and individual observations, such accuracy was thought of too little importance to make these tables very complex, and thus to increase the labor of computation; for if we had a theory and tables absolutely perfect, so great are the various abnormal effects which cannot be taken into the theory that there would scarcely be any perceptible decrease of the residuals.

No attempt has been made to determine the meteorological effect upon the *times* of the tides. These are, no doubt, very great in individual cases, but it is doubtful whether much of these effects could be represented by any arguments. The times, therefore, as represented in the sketch, are entirely uncorrected for any of these effects. The very nature, also, of such observations renders them inaccurate; for very small errors change considerably the mere time of the

maximum or minimum. Very small abnormal effects also, about these times, may affect very much the observed time of the maximum or minimum. If the general sea-level is rising about the time of high water from a change of barometric pressure or the winds, the time of the maximum is later, and the reverse, if it is falling at that time. The abnormal oscillations of various periods, which are always observed more or less, may also affect very much the time-observations. In forming the tables, also, it was seen that the effect of the lunar and solar diurnal tides in all their various relative phases upon the mere times of high and low water could not be accurately represented in all individual cases without making the tables very complex.

The average of all the residuals, uncorrected for any meteorological effects, belonging to the six years, are as follows:

Year.	H. W.	L. W.	Mean.
	Feet.	*Feet.*	*Feet.*
1856....	0.44	0.43	0.44
1857....	0.50	0.49	0.50
1858....	0.36	0.35	0.36
1859....	0.31	0.35	0.33
1860....	0.36	0.35	0.36
1861....	0.33	0.37	0.35

The residuals of the first two years are generally much larger than those of the following years, and the effect is seen in the averages. There was a change of observer in August, 1857.

By taking the monthly averages of the residuals in the heights for the last four years, and of the residuals in the times for the year 1858 only, we get—

	Feet.	*Min.*
January	0.52	7.4
February	0.44	5.2
March	0.40	6.6
April	0.36	5.0
May	0.30	4.5
June	0.27	3.9
July	0.27	4.3
August	0.31	4.7
September	0.32	5.0
October	0.39	6.2
November	0.37	8.0
December	0.44	8.6

It is seen that in both the heights and the times the residuals are only about half as great in summer as in winter. This shows that the residuals are due mostly to meteorological effects, and that they are least in summer, because the meteorological changes are then least. If, then, these effects were entirely absent, the residuals would be still much more reduced.

The computations of the tides from the formulas and tables were made mostly by Mr. J. G. Spaulding, aid in the Coast Survey, and they seem to have been made with great accuracy and faithfulness throughout.

Very respectfully, yours,

WM. FERREL.

Prof. BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

APPENDIX No. 7.

METEOROLOGICAL REGISTER, ALASKA TERRITORY, 1870–'71.

Saint Paul's Island.—Latitude, 57° N.; longitude, 170° W. of Greenwich.—Observer, Capt. Charles Bryant.

[The station is forty feet above tide-level.]

FAIRHAVEN, MASS., *October* 2, 1871.

SIR: I have the honor to transmit the inclosed copies of a meteorological record kept by myself while on official duty at Saint Paul's Island, Alaska Territory, from November, 1870, to July, 1871, inclusive. This being the first winter record kept at that point since the cession of the Territory to the United States by Russia, it is proper to state that the cold during February, March, and April, 1871, was considered unusually severe by the oldest native inhabitants.

Yours, truly,

CHARLES BRYANT,
Special Agent Treasury Department.

Prof. BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

Meteorological register for Saint Paul's Island, Alaska Territory.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

NOVEMBER, 1870.

Date.	Thermometer.			Movements of atmosphere.									Amount of cloudiness.			Snow or rain.	Barometer and thermometer attached.						Remarks.
				7 a. m.			2 p. m.			9 p. m.							7 a. m.		2 p. m.		9 p. m.		
	7 a. m.	2 p. m.	9 p. m.	Winds. D.	Winds. F.	Motion of clouds.	Winds. D.	Winds. F.	Motion of clouds.	Winds. D.	Winds. F.	Motion of clouds.	7 a. m.	2 p. m.	9 p. m.		Barometer.	Therm'ter.	Barometer.	Therm'ter.	Barometer.	Therm'ter.	
1870.																							
Nov. 1	30	40	34	S.W.	1	N. E.	S.W.	1	N. E.	S.W.	1	E.	3	4	3	.09	......	..	29.78	35	29.72	40	Snow and rain.
2	32	37	31	N. W.	6	S. E.	N. W.	4	S. E.	N. W.	4	S. E.	8	7	1	.12	29.68	33	29.72	37	29.80	34	Snow.
3	31	32	31	N. W.	1	S. E.	N. W.	3	S. E.	N. W.	3	S. E.	4	4	3	.06	29.84	34	29.68	36	29.68	35	Squalls of snow.
4	29	32	31	N. W.	1	E.	W.	1	S.W.	S. E.	4	N. W.	4	7	8	.03	30.04	34	30.12	34	29.90	32	Snow in squalls.
5	34	39	34	S. E.	4	N. W.	S.W.	3	E.	S.W.	2	E.	4	3	4	.15	29.10	34	29.12	38	29.28	34	During the night a fierce
6	35	32	29	N.	1	S.	N.	2	S. E.	N. W.	2	S. E.	8	8	8	.03	29.09	40	29.22	36	29.50	36	gale with wind.
7	28	33	33	0	0	0	N.	1	S.	N. W.	1	S. E.	0	5	8	.00	29.62	34	29.75	36	29.72	35	
8	35	35	35	S. E.	3	N. W.	S. E.	1	N. W.	E.	6	S. E.	8	8	8	.24	29.12	37	28.56	38	27.85	41	Rain. Twelve hours after
9	32	30	27	N.	4	S.	N. W.	3	S. E.	N. W.	2	S. E.	8	6	2	.07	28.38	37	28.75	36	29.00	30	the sudden fall of the ba-
10	22	32	33	N. W.	1	S. E.	N. W.	1	S. E.	N.	1	S.	0	7	6	.00	29.44	26	29.48	35	29.44	33	rometer a fierce gale blew
11	31	35	33	N. E.	1	S.W.	N. E.	1	S.W.	N. E.	5	S.W.	7	8	8	.10	29.24	34	29.08	39	28.87	35	from southeast, raising the
12	36	37	33	S. E.	3	N. W.	S. E.	3	N. W.	N. E.	5	S.W.	7	7	8	.02	28.84	37	28.94	44	29.18	36	sea on that side six feet
13	29	32	37	N.	1	S.	N. E.	1	S.W.	N.	1	S.	4	3	3	.02	29.38	34	29.34	34	29.20	33	above the ordinary level,
14	31	34	34	N. E.	2	S.W.	N. E.	1	S.W.	N. E.	3	S.W.	4	8	8	.00	28.95	34	29.90	40	28.95	42	flooding the flats in front of
15	32	31	21	N.	1	S.	N.	1	S.	N.	1	S.	2	8	8	.00	29.05	36	29.08	38	29.05	34	the village. The same oc-
16	35	34	31	N. W.	1	S. E.	N. W.	1	S. E.	N. W.	2	S. E.	7	8	8	.00	29.02	37	29.00	37	29.10	37	curred at the same date in
17	31	32	29	N.	1	S.	N.	1	S.	N.	1	S.	1	4	5	.00	29.14	34	29.23	34	29.28	31	1869, doing much damage.
18	29	33	34	N.	1	S.	N. E.	2	S.W.	E.	2	S	5	8	8	.01	29.21	33	29.11	37	29.00	36	Rainy.
19	34	38	36	N. E.	3	N.	N. E.	2	S.W.	N. E.	4	S.W.	8	8	8	.20	28.94	37	28.85	45	28.72	43	
20	33	34	31	N. E.	3	S.W.	N. E.	2	S.W.	N. E.	3	S.W.	8	7	7	.03	28.60	43	28.61	42	28.50	34	
21	31	30	29	N. E.	1	S.W.	N. W.	2	S. E.	N. W.	3	S. E.	7	8	8	.02	28.70	33	28.68	34	28.72	33	
22	28	30	29	N. W.	1	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	8	6	1	.00	28.84	31	28.94	33	28.86	32	
23	28	30	29	0	0	0	W.	1	E.	S. E.	1	N. W.	6	3	1	.04	28.86	31	28.88	33	28.95	31	
24	31	32	29	S.W.	1	N. E.	S.W.	1	N. E.	S. W.	2	N. E.	6	4	3	.04	29.04	32	29.06	33	29.12	31	
25	32	31	27	S. E.	1	N. W.	S. E.	1	N. W.	0	0	0	1	5	4	.05	29.24	32	29.24	33	29.28	30	
26	29	30	30	W.	3	E.	W.	2	E.	0	0	0	6	4	1	.07	29.54	31	29.68	31	29.76	31	
27	31	38	35	N. W.	4	S. E.	S.W.	1	N. E.	S.W.	1	N. E.	8	6	7	.15	29.72	33	29.66	40	29.76	40	
28	34	38	37	N. E.	5	S.W.	N. E.	3	S.W.	E.	2	W.	8	8	8	.22	29.26	46	28.98	47	28.78	42	Rainy.
29	31	33	27	S.W.	2	N. E.	S.	1	N.	S.W.	5	N. E.	1	8	8	.06	29.10	32	29.00	34	28.92	31	Rain and snow.
30	29	32	35	W.	1	E.	S. W.	2	N. E.	S.W.	1	N. E.	4	4	4	.11	29.43	32	29.64	38	29.80	36	

Average daily mean, thermometer, 32°.15; warmest day, (12th,) mean, 35°.33; coldest day, (10th,) mean, 29°.00; cloudiness, 0.69; rain-fall, inches, 1.91.

Meteorological register for Saint Paul's Island, Alaska Territory—Continued.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

DECEMBER, 1870.

Date.	Thermometer. 7 a.m.	Thermometer. 2 p.m.	Thermometer. 9 p.m.	Movements of atmosphere. 7 a.m. Winds. D.	7 a.m. Winds. F.	7 a.m. Motion of clouds.	2 p.m. Winds. D.	2 p.m. Winds. F.	2 p.m. Motion of clouds.	9 p.m. Winds. D.	9 p.m. Winds. F.	9 p.m. Motion of clouds.	Amount of cloudiness. 7 a.m.	Amount of cloudiness. 2 p.m.	Amount of cloudiness. 9 p.m.	Snow or rain.	Barometer and thermometer attached. 7 a.m. Barometer.	7 a.m. Therm'ter.	2 p.m. Barometer.	2 p.m. Therm'ter.	9 p.m. Barometer.	9 p.m. Therm'ter.	Remarks.
1870.																							
Dec. 1	36	37	33	S. E.	2	N. W.	S. E.	2	N. W.	S. E.	2	N. W.	8	8	0	.14	29.56	36	29.58	42	29.58	35	Light rain.
2	34	33	32	W.	1	E.	W.	2	S. E.	S. E.	1	N. W.	1	3	1	.04	29.54	34	29.72	34	29.73	34	
3	38	39	38	S. E.	2	N. W.	S. E.	3	N. W.	S. E.	3	N. W.	8	8	8	.70	29.25	40	29.10	40	28.92	41	Rain.
4	32	31	32	S. W.	5	N. E.	S. W.	5	N. E.	N. W.	4	S. E.	8	8	7	.33	29 10	32	29.62	34	30.10	34	
5	34	36	31	N. W.	1	S. E.	W.	1	E.	W.	1	W.	8	8	2	.06	30.26	38	30.32	44	30.30	42	
6	34	33	37	N. E.	1	S. W.	N. E.	2	S. E.	E.	3	0	8	6	0	.00	29.96	38	29.74	44	29.58	37	
7	28	26	22	N. E.	3	S. W.	N. E.	3	S. W.	N. E.	3	S. W.	5	5	4	.00	29.30	35	29.23	34	29.23	25	
8	22	24	28	N.	1	S.	N. E.	1	S. W.	E.	5	0	8	8	8	.06	29.22	27	29.15	26	28.84	30	
9	32	32	30	S.	1	N.	S.	2	N.	S.	3	N.	3	8	2	.03	28.83	34	28.94	33	28.98	32	Light fall of snow.
10	32	31	32	S. W.	1	N. E.	S. W.	1	N. E.	S. W.	1	N. E.	1	3	1	.11	29.14	33	29.36	35	29.40	34	
11	34	34	36	E.	1	W.	E.	1	W.	E.	3	W.	8	8	8	.20	29.40	37	29.34	37	29.04	38	Squally, with snow.
12	34	31	32	S. E.	3	N. W.	S. E.	5	N. W.	E.	1	W.	1	5	1	.02	28.65	34	28.75	33	28.96	33	
13	34	36	32	E.	1	W.	E.	4	W.	N. E.	1	S. W.	8	8	8	.05	29.05	37	28.96	38	29.05	36	During the night snow fell to
14	30	30	29	N. E.	1	S. W.	N. E.	1	S. W.	N. E.	1	0	1	1	0	.05	29.15	35	29.26	35	29.30	34	the depth of two inches.
15	32	33	32	N. E.	2	S. W.	N. E.	1	S. W.	N. E.	2	S. W.	6	7	6	.03	29.25	35	29.15	37	29.20	34	
16	32	34	34	S. E.	1	N. W.	S.	1	0	N. E.	4	S. W.	0	8	8	.07	29.42	34	29.46	36	29.45	37	
17	34	34	36	N. E.	4	S. W.	N.	2	S.	N. E.	4	S. W.	8	8	8	.12	29.40	40	29.43	38	29.42	41	Light rain.
18	35	34	36	N. E.	1	S. W.	N. E.	2	S. W.	N. E.	1	S. W.	7	8	4	.13	29.66	46	29.48	46	29.85	44	
19	34	36	36	N. E.	1	S. W.	N. E.	1	S. W.	N. E.	3	S. W.	4	6	8	.00	29.80	42	29.80	48	29.75	43	
20	34	32	30	N. E.	3	S. W.	N. E.	3	S. W.	N. E.	2	S. W.	8	8	8	.06	29.49	41	29.29	35	29.15	33	
21	30	28	28	0	0	0	N. E.	2	S. W.	S. W.	1	N. E.	7	7	8	.05	29.32	32	29.48	32	29.88	30	Rain and snow.
22	23	28	25	S. W.	1	N. E.	0	0	0	N. W.	1	N. W.	8	8	8	.00	30.10	30	30.14	30	30.14	28	
23	22	21	19	N. W.	1	0	N. W.	2	S. E.	N. W.	6	S. E.	0	8	2	.00	29.96	27	29.86	25	29.75	22	Snow.
24	16	16	17	N. W.	7	S. E.	N. W.	6	S. E.	N. W.	4	S. E.	8	8	8	.01	29.36	20	29.26	25	29.29	24	
25	20	21	22	N. W.	6	S. E.	N. W.	6	S. E.	N. W.	6	S. E.	8	8	8	.01	29.15	22	29.15	24	29.22	27	
26	20	20	17	N. W.	5	S. E.	N.	3	S.	N.	6	S.	4	2	1	.01	29.25	25	29.28	23	29.32	22	
27	16	14	14	N. W.	6	S. E.	N. W.	6	S. E.	N. W.	6	S. E.	8	6	4	.00	29.42	18	29.48	16	29.62	16	Snow.
28	18	19	20	N. E.	1	S.	N. W.	2	S.	N. W.	4	S. E.	8	8	6	.02	29.58	21	29.50	22	29.58	21	
29	10	10	10	N. W.	4	S.	N. W.	4	S.	N. W.	4	S.	5	7	6	.00	29.70	13	29.76	20	29.88	17	
30	11	10	7	N. W.	1	S.	N. W.	4	S. E.	N. W.	5	S. E.	7	6	6	.00	29.92	16	29.92	15	29.94	11	
31	8	8	10	N. W.	6	S. E.	N. W.	5	S. E.	N. W.	5	S. E.	6	7	7	.00	29.08	12	30.12	11	30.20	14	

Average daily mean, thermometer, 27°.39; coldest day, (31st,) mean, 8°.66; Cloudiness, 0.72; rain-fall, inches, 2.30.

Meteorological register for Saint Paul's Island, Alaska Territory—Continued.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

JANUARY, 1871.

Date.	Thermometer. 7 a. m.	Thermometer. 2 p. m.	Thermometer. 9 p. m.	Movements of atmosphere. 7 a. m. Winds. D.	7 a. m. Winds. F.	7 a. m. Motion of clouds.	2 p. m. Winds. D.	2 p. m. Winds. F.	2 p. m. Motion of clouds.	9 p. m. Winds. D.	9 p. m. Winds. F.	9 p. m. Motion of clouds.	Amount of cloudiness. 7 a. m.	Amount of cloudiness. 2 p. m.	Amount of cloudiness. 9 p. m.	Snow or rain.	Barometer and thermometer attached. 7 a. m. Barometer.	7 a. m. Therm'ter.	2 p. m. Barometer.	2 p. m. Therm'ter.	9 p. m. Barometer.	9 p. m. Therm'ter.	Remarks.
1871.																							
Jan. 1	10	8	9	N. W.	5	S. E.	N. W.	1	S. E.	N. W.	2	S. E.	8	6	5	.00	30.20	13	30.20	11	30.20	13	Very fine weather.
2	12	12	12	N. W.	3	S. E.	N. W.	1	0	N. W.	1	0	0	0	0	.00	30.24	15	30.18	18	30.18	15	
3	14	21	20	N. W.	1	0	N.	1	0	N.	1	0	0	1	1	.00	30.17	18	30.16	26	30.22	24	Clear and fine.
4	16	20	19	N.	0	0	N. E.	1	0	0	0	0	0	1	1	.00	30.35	22	30.40	26	30.33	23	
5	28	29	28	0	0	0	0	0	0	0	0	0	8	8	7	.00	30.35	30	30.35	31	30.30	31	Large bodies of drift-ice in
6	29	31	31	S. E.	1	N. W.	S. E.	1	N. W.	S. E.	1	N. W.	7	8	8	.00	30.22	31	30.18	31	30.08	32	sight to northeast.
7	34	33	26	S. E.	1	0	S. E.	1	0	0	0	0	8	8	0	.00	30.00	35	30.05	37	30.15	31	
8	25	30	31	N. E.	2	0	N. E.	3	0	N. E.	3	S. E.	3	8	8	.01	30.12	27	30.09	35	29.78	35	Light snow.
9	33	33	31	E.	1	0	E.	3	0	W.	2	E.	8	8	4	.06	29.57	37	29.47	37	29.42	35	Light rain.
10	24	24	22	N. W.	5	S. E.	W.	5	E.	W.	5	E.	4	7	7	.01	29.48	25	29.56	37	29.72	25	
11	21	21	20	N. W.	1	S. E.	N. W.	1	W.	0	0	0	7	3	7	.00	29.84	25	29.81	24	29.80	24	Snow in squalls, but very
12	21	26	26	N. E.	2	S.W.	N. E.	5	S.W.	N. E.	6	0	8	8	8	.00	29.55	26	29.36	27	29.08	30	light.
13	31	33	33	E.	5	W.	E.	4	W.	S. E.	6	N. W.	8	8	8	.03	28.74	36	28.75	36	28.88	37	
14	32	31	30	N. E.	3	0	S. E.	1	W.	0	0	0	8	3	1	.07	29.02	35	29.08	33	29.18	37	Light rain.
15	27	32	29	N. W.	1	0	0	0	0	S.	1	0	1	2	2	.00	29.50	29	29.48	33	29.50	35	Rainy.
16	31	32	29	N. E.	3	0	N. E.	3	0	N. E.	3	0	8	8	8	.03	29.30	33	29.16	35	28.98	36	
17	30	32	30	W.	1	0	0	0	0	0	0	0	1	8	4	.00	28.96	33	28.98	33	29.09	32	
18	29	30	23	N.	1	0	S.W.	1	0	0	0	0	1	7	0	.00	29.29	32	29.45	33	29.50	30	
19	26	32	28	0	0	0	S.W.	1	0	0	0	0	0	3	0	.00	29.57	33	29.54	35	29.35	30	
20	29	27	28	N. E.	5	0	N. E.	5	S.W.	N. E.	5	S.W.	8	8	8	.05	28.98	33	28.86	37	28.78	34	Snow.
21	28	34	28	N. E.	1	0	N. E.	1	0	0	0	0	8	3	0	.02	28.60	32	28.60	39	28.86	34	
22	28	30	30	N. E.	1	0	N. E.	1	0	N. W.	5	S. E.	7	7	8	.02	28.94	32	28.93	32	28.64	35	
23	33	33	30	E.	4	S.W.	S. E.	4	N. W.	S. E.	1	0	8	4	1	.00	28.50	35	28.83	34	29.08	32	
24	33	33	30	N.	1	0	N. E.	2	S.W.	E.	1	0	8	3	0	.00	29.00	38	29.25	34	29.12	32	
25	29	29	32	E.	1	W.	E.	2	S.W.	S. E.	1	0	6	7	8	.00	29.10	33	28.95	36	28.94	36	
26	31	30	26	N. E.	1	W.	N. E.	1	W.	0	0	0	6	7	6	.01	29.86	36	28.78	33	28.60	36	
27	29	34	30	0	0	S.W.	0	0	0	N. E.	1	S.W.	7	6	3	.00	28.64	36	28.68	34	28.74	35	
28	29	36	31	0	0	0	N. E.	1	S.W.	N. E.	1	S.W.	3	6	1	.00	28.74	32	28.77	38	28.88	38	
29	31	32	25	N. E.	1	S.W.	N. E.	1	S.W.	N.	1	S.	5	6	8	.00	28.86	36	28.86	37	28.90	30	A fierce gale from northwest,
30	28	28	25	0	0	0	N. W.	7	S. E.	N. W.	7	S. E.	8	8	8	....	28.90	31	28.78	35	28.55	29	with driving snow; estimat-
31	28	28	27	N. W.	6	S. E.	N. W.	4	0	N.	4	0	8	8	8	....	28.29	31	28.32	35	28.55	27	ed depth of fall, 8 inches.

Average daily mean, thermometer, 27°.66; coldest day, (1st,) 9°.00; cloudiness, 0.63; rain-fall, inch, 0.25.

During the afternoon of the 5th, large bodies of drift-ice were seen approaching the island from northeast; dividing on the east end, a portion passed on the southeast side. On the night of the 7th, the southeast wind drove it to the north, and it passed the island. This ice contained sand and gravel; and some of the higher portions were coated with sand, as if it formed near a shore, and the dirt was blown on it by the wind. After the 7th no more of it was seen.

Meteorological register for Saint Paul's Island, Alaska Territory—Continued.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

FEBRUARY, 1871.

Date.	Thermometer. 7 a. m.	Thermometer. 2 p. m.	Thermometer. 9 p. m.	Movements of atmosphere. 7 a. m. Winds. D.	7 a. m. Winds. F.	7 a. m. Motion of clouds.	2 p. m. Winds. D.	2 p. m. Winds. F.	2 p. m. Motion of clouds.	9 p. m. Winds. D.	9 p. m. Winds. F.	9 p. m. Motion of clouds.	Amount of cloudiness. 7 a. m.	2 p. m.	9 p. m.	Rain-fall.	Barometer and thermometer attached. 7 a. m. Barometer.	7 a. m. Therm'ter.	2 p. m. Barometer.	2 p. m. Therm'ter.	9 p. m. Barometer.	9 p. m. Therm'ter.	Remarks.
1871.																							
Feb. 1	22	21	19	W.	5	0	N. W.	5	0	N. W.	5	0	8	8	8	....	28. 95	27	29. 02	25	29. 14	24	Squalls of wind and snow.
2	19	19	17	0	0	0	N. W.	1	0	0	0	0	8	8	6	..	29. 24	24	29. 22	31	29. 20	25	Ice in sight to northeast.
3	17	20	22	0	0	0	N. E.	1	S. W.	N. E.	2	S. W.	4	7	8	....	29. 18	23	29. 20	25	29. 30	27	Large bodies of drift-ice along the southeast shore.
4	22	23	22	N. W.	1	S. E.	N. W.	1	0	0	0	0	7	8	7	....	29. 44	30	29. 50	28	29. 57	28	Detached belts of porridge-ice passing with the tide.
5	31	28	24	N. W.	1	0	N. W.	1	S.	0	0	0	8	6	0	....	29. 34	35	29. 34	36	29. 35	35	
6	23	22	21	N.	1	S. W	N.	3	S.	N. W.	5	S. E.	7	8	8	..	29. 40	30	29. 50	38	29. 30	40	Snow.
7	22	31	30	N.	1	S. E.	N.	1	0	N. E.	3	S.	7	8	8	..	29. 36	28	29. 38	35	29. 24	35	
8	32	32	33	N. E.	3	S. W.	N. E.	3	S. W.	E.	2	S. W.	8	8	3	....	29. 00	36	28. 84	34	28. 80	35	•
9	33	34	32	E.	5	W.	E.	4	W.	E.	3	W.	8	8	1	....	28. 78	35	28. 96	36	28. 96	35	Light rain.
10	32	31	31	N. E.	2	S. W.	N. E.	3	S. W.	N. E.	3	S. W.	8	8	8	....	28. 96	35	28. 65	36	28. 61	33	Snow mixed with rain.
11	32	34	30	N. E.	1	S. W.	N. E.	1	S. W.	N. W.	1	0	8	8	6	....	28. 70	37	28. 74	36	28. 83	34	
12	30	33	31	W.	1	0	W.	1	E.	S. E.	3	N. W.	8	6	4	....	28. 99	34	29. 24	39	29. 24	34	
13	31	30	34	S. E.	1	W.	S. W.	3	N. E.	S. W.	1	N.	4	5	3	....	29. 36	33	29. 46	35	29. 51	34	Heavy squalls of wind with snow.
14	32	34	31	E.	1	S. W.	N. E.	3	0	N. W.	5	0	4	8	8	...	29. 48	33	29. 28	34	29. 05	32	
15	28	26	30	N. W.	6	S. E.	N.	5	0	N.	5	0	8	8	8	...	29. 04	32	29. 14	32	29. 34	35	
16	29	23	15	N.	1	0	N. W.	3	0	N.	1	S. W.	8	3	4	....	29. 56	32	29. 62	32	29. 64	23	
17	15	17	5	N. W.	2	0	N. W.	1	S. E.	N. W.	2	0	8	7	8	....	29. 50	22	29. 46	24	29. 54	20	
18	4	12	9	N. W.	1	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	3	2	5	...	29. 65	18	29. 68	20	29. 58	15	
19	5	9	−6	N. W.	1	S. E.	N.	3	0	N. W.	2	0	4	4	3	....	29. 85	23	29. 96	13	29. 98	10	Island entirely surrounded by drift-ice.
20	5	13	16	N.	2	0	N.	7	0	N.	5	0	8	8	8	....	29. 70	10	29. 60	15	29. 39	22	Light snow.
21	17	17	19	N.	6	0	N. W.	3	S. E.	N.	6	0	4	7	2	....	28. 78	19	28. 72	20	29. 14	30	Snow.
22	9	9	3	N. W	4	S. E.	N. W.	4	S. E	N. W.	1	0	6	4	2	....	29. 51	21	29. 65	20	29. 70	23	
23	2	5	2	N. W.	2	S. E.	N. W.	3	S. E.	N. W.	4	S. E.	2	1	1	....	29. 46	20	29. 38	25	29. 36	25	
24	8	8	4	N. W.	2	S. E.	N. W.	3	S. E.	N. W.	1	S. E.	1	1	0	....	29. 44	19	29. 58	24	29. 68	25	Very clear.
25	8	12	0	N.	1	E.	N. W.	1	S. E.	0	0	0	2	5	4	....	29. 74	15	29. 82	22	29. 78	15	Very clear.
26	6	12	4	N. E.	1	S. E.	N. W.	2	S. E.	N.	1	0	2	4	8	....	29. 69	9	29. 65	22	29. 68	23	Clear.
27	4	13	2	N. W.	1	S. E.	N.	1	S. E.	N. W.	1	0	8	5	4	....	29. 75	20	29. 82	26	29. 88	22	Hazy.
28	1	12	−1	N. W.	1	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	1	2	4	....	29. 88	13	29. 88	20	29. 88	22	Very clear.

Average daily mean, thermometer, 18°.66; coldest day, (19th,) mean, 2°.66; cloudiness, 0.68; snow, inches, 24.

Meteorological register for Saint Paul's Island, Alaska Territory—Continued.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

MARCH, 1871.

Date.	Thermometer. 7 a.m.	Thermometer. 2 p.m.	Thermometer. 9 p.m.	Movements of atmosphere. 7 a.m. Winds. D.	7 a.m. Winds. F.	7 a.m. Motion of clouds.	2 p.m. Winds. D.	2 p.m. Winds. F.	2 p.m. Motion of clouds.	9 p.m. Winds. D.	9 p.m. Winds. F.	9 p.m. Motion of clouds.	Amount of cloudiness. 7 a.m.	Amount of cloudiness. 2 p.m.	Amount of cloudiness. 9 p.m.	Rain fall.	Barometer and thermometer attached. 7 a.m. Barometer.	7 a.m. Therm'ter.	2 p.m. Barometer.	2 p.m. Therm'ter.	9 p.m. Barometer.	9 p.m. Therm'ter.	Remarks.
1871.																							
Mar. 1	2	2	0	N. W.	1	0	N. W.	1	S. E.	N. W.	1	S. E.	1	2	4	....	29. 88	13	29. 86	13	29. 82	9	
2	−2	−2	−5	N. W.	1	S. E.	N. W.	1	S. E.	0	0	0	1	0	0	....	29. 84	13	29. 86	15	29, 82	1	
3	−3	6	5	N.	1	0	N.	1	0	N.	1	0	0	0	1	....	29. 72	0	29. 65	11	29. 64	13	Very clear and serene
4	5	5	10	N.	1	0	N.	1	0	N.	1	S.	0	0	3	....	29. 55	14	29. 53	21	29. 52	18	weather; the island en-
5	5	6	0	N. W.	1	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	1	1	2	....	29. 58	9	29. 70	9	29. 73	13	tirely surrounded by large
6	−3	3	1	N. W.	1	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	1	4	4	....	29. 55	9	29. 44	13	29. 45	19	bodies of ice, about three
7	0	6	4	N. W	2	S. E.	N. W.	2	S. E.	N. W.	2	S. E.	3	4	6	....	29. 49	10	29. 58	17	29 50	17	feet in thickness, ap-
8	5	9	1	N. W.	1	0	N. W.	1	0	0	0	0	4	1	0	....	29. 61	11	29. 68	20	29. 69	19	proaching from northeast,
9	2	9	7	N.	1	0	N.	1	0	N.	1	0	1	1	1	....	29. 60	12	29. 58	19	29. 55	12	and slowly drifting past
10	4	11	12	N.	1	S. E.	N.	1	S. E.	N.	1	S. E.	1	1	1	....	29. 40	12	29. 49	22	29. 48	13	with the tide to the south-
11	12	9	5	N. W.	3	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	8	3	1	....	29. 50	22	29. 75	29	29. 84	26	west.
12	7	12	7	N.	1	0	N.	1	0	N.	1	0	0	0	0	....	29. 71	22	29. 82	32	29. 85	31	
13	8	10	10	N.	1	0	N.	1	S. E.	N.	1	S. E.	0	7	8	....	29. 80	26	29. 85	28	29. 88	30	
14	4	11	4	N.	1	0	N.	1	0	0	0	0	0	0	0	....	29 87	19	29. 92	32	29. 90	25	
15	7	12	7	N.	1	0	N.	1	0	N. E.	2	S. W.	2	1	3	....	29. 88	17	29. 84	25	29. 74	15	The drifting ice stained with
16	8	12	11	N.	1	S. E.	N. E.	3	S. W.	N. E.	3	S. W.	2	1	3	....	29. 68	13	29. 61	23	29. 48	17	mud and gravel.
17	17	18	17	N. E.	3	S. W.	E.	3	S. W.	N.	3	S. W.	6	8	1	....	29. 26	18	29. 16	21	29. 14	19	
18	21	26	16	N. E.	2	S. W.	N.	2	S. E.	N. E.	1	S. W.	8	7	4	....	29. 25	23	29. 36	29	29. 54	31	
19	15	14	6	N. E.	1	S. W.	N. E.	1	S. W.	N. E.	1	0	1	1	1	....	29. 64	25	29. 74	29	29. 72	28	
20	10	12	12	N. E.	2	S. W.	N.	3	S.	N.	1	S.	7	7	1	....	29. 50	13	29. 46	29	29. 52	31	
21	12	23	13	N.	1	0	N.	1	0	0	0	0	8	8	8	....	29. 52	22	29. 51	29	29. 42	30	
22	12	16	12	N. W.	1	S.	N. W.	1	S. E.	0	0	0	1	1	1	....	29. 16	28	29. 06	36	28. 94	20	
23	17	26	20	N.	2	S. E.	N. W.	2	S. E.	N. E.	3	S. W.	8	8	1	....	28. 91	28	28. 93	36	28. 95	38	
24	17	22	9	N. W.	2	S. E.	N. W.	3	S. E.	N. W.	4	E.	8	8	8	....	28. 94	35	28. 91	38	28. 89	38	
25	8	14	8	N. W.	3	S. E.	N. W.	3	S. E.	N. W.	3	S. E.	8	8	8	....	28. 90	27	28. 98	36	28. 00	30	
26	11	7	4	N. W.	2	S. E.	N. W.	2	S. E.	N. W.	2	S. E.	7	3	3	....	29. 05	21	29. 20	25	29. 28	18	
27	5	18	0	N. W.	1	S. E.	N. W.	1	S. E.	0	0	0	2	3	0	....	29. 36	18	29. 48	25	29. 49	24	
28	8	13	8	N. W.	1	0	N. E.	2	S. W.	N. E.	2	S. W.	8	8	7	....	29. 45	18	29. 44	19	29. 42	26	
29	18	18	18	0	0	0	N. W.	1	0	N. W.	1	S. E.	7	2	1	....	29. 32	27	29. 29	34	29. 24	35	
30	22	26	20	0	0	0	N. W.	1	0	0	0	0	8	8	8	....	29. 20	24	29. 24	33	29. 96	35	The weather for the entire
31	22	28	15	N.	1	N. E.	N. W.	2	S. E.	N. W.	2	S. E.	8	8	8	....	29. 33	28	29. 46	37	29. 60	30	month very fine and clear.

Average daily mean, thermometer, 9°.80; coldest day, (2d,) 3° below zero; cloudiness, 0°.44; snow, inches, 40.

Meteorological register for Saint Paul's Island, Alaska Territory—Continued.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

APRIL, 1871.

Date.	Thermometer.			Movements of atmosphere.									Amount of cloudiness.				Barometer and thermometer attached.						Remarks.
				7 a. m.			2 p. m.			9 p. m.							7 a. m.		2 p. m.		9 p. m.		
				Winds.		Motion of clouds.	Winds.		Motion of clouds.	Winds.		Motion of clouds.											
	7 a. m.	2 p. m.	9 p. m.	D.	F.		D.	F.		D.	F.		7 a. m.	2 p. m.	9 p. m.	Rain-fall.	Barometer.	Therm'ter.	Barometer.	Therm'ter.	Barometer.	Therm'ter.	
1871.																							
April 1	12	17	10	N. W.	3	S. E.	N. W.	2	S. E.	0	0	0	8	8	8	....	29.85	28	29.98	29	30.05	25	Very clear; ice very heavy, drifting past.
2	29	28	32	E.	5	0	E.	6	W.	E.	5	0	1	1	0	.07	29.66	23	29.06	31	28.76	33	Snow and rain.
3	34	43	29	S.	1	0	S.	1	0	S.	1	N. W.	8	8	1	....	28.95	32	29.05	36	29.10	37	
4	32	36	32	S. E.	1	0	S.	1	0	S. E.	1	N. W.	7	4	7	....	29.38	34	29.45	36	29.44	36	
5	32	34	29	E.	1	S. W.	E.	1	0	N. E.	1	S. W.	7	8	8	....	29.34	32	29.40	34	29.38	38	
6	34	36	31	E.	1	0	E.	1	0	S. E.	1	S. W.	2	1	7	....	29.48	36	29.55	38	29.56	37	
7	31	32	28	E.	1	S. W.	N. E.	1	S. W.	N. E.	1	0	6	7	1	....	29.58	33	29.51	34	29.49	32	
8	28	28	25	N. E.	3	0	N. E.	2	0	0	0	0	8	8	0	....	29.26	32	29.34	38	29.22	40	
9	22	21	19	N.	1	0	N. W.	1	0	N. W.	1	S. E.	6	7	8	....	29.18	38	29.18	31	29.24	32	
10	21	26	21	S. W.	1	N. E.	S. W.	1	N. E.	0	0	0	8	4	1	....	29.35	32	29.49	34	29.64	33	
11	31	32	30	S.	1	0	E.	1	0	E.	1	0	7	7	1	....	29.65	33	29.69	34	29.69	34	
12	30	30	28	N. E.	4	S. W.	N.	4	S.	N. E.	4	S.	8	8	8	....	29.50	33	29.16	34	29.12	31	
13	30	34	29	N. E.	3	S. W.	N. E.	3	S. W.	N.	3	0	8	8	1	....	29.16	31	29.24	36	29.50	35	The ice appears to be not much broken up.
14	33	36	28	N. E.	1	0	N. E.	1	0	N. E.	3	0	8	8	8	....	29.74	35	29.84	38	29.74	34	
15	32	33	30	E.	2	W.	E.	2	W.	E.	2	0	8	8	1	....	29.50	34	29.55	34	29.29	34	
16	33	31	30	N.	1	S.	W.	4	S. E.	N. W.	4	S. E.	4	8	8	....	29.16	35	29.04	38	29.16	40	Belts of open water in sight to eastward.
17	28	29	22	N. W.	2	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	8	8	8	....	29.21	37	29.18	36	29.22	27	
18	27	34	28	N. W.	2	S. E.	N. W.	1	0	N. W.	1	0	8	8	8	....	29.20	36	29.24	40	29.28	35	
19	29	32	28	N. W.	2	0	N. W.	2	S. E.	N. W.	2	S. E.	8	8	8	....	29.28	35	29.42	38	29.50	40	
20	28	34	28	N. W.	2	S. W.	N. W.	2	S. E.	N. W.	3	S. E.	8	7	7	....	29.58	38	29.56	42	29.80	42	
21	28	30	24	N. W.	3	S. E.	N. W.	3	S. E.	N. W.	4	S. E.	8	7	8	....	29.76	38	29.66	46	29.59	45	
22	26	35	30	N. W.	3	0	N. W.	1	0	0	0	0	8	8	8	....	29.10	32	29.00	44	28.98	42	Ice closed in solid in all directions.
23	34	26	26	N. E.	1	0	E.	1	0	E.	1	0	8	8	1	....	28.94	35	29.00	36	29.09	30	
24	34	38	27	E.	1	0	E.	1	0	0	0	0	1	0	0	....	29.29	35	29.46	42	29.54	37	Very fine weather.
25	35	38	32	0	0	0	S. E.	1	0	0	0	0	0	1	7	....	29.74	40	29.84	42	29.88	35	
26	32	36	30	E.	1	W.	E.	2	W.	E.	3	W.	4	7	8	....	29.82	34	29.66	37	29.30	33	
27	33	36	31	S. E.	1	0	E.	1	0	0	0	0	1	8	4	....	29.02	34	29.05	37	29.11	37	Snow.
28	33	36	29	N. E.	1	0	N. E.	1	S. W.	N. E.	2	S. W.	8	8	8	....	29.22	41	29.32	40	29.40	37	Foggy.
29	27	28	24	N.	2	S.	N.	2	S.	N.	1	S.	6	8	8	....	29.49	32	29.56	40	29.53	38	
30	22	28	21	N.	1	S.	N.	2	S.	N.	1	S.	8	7	7	....	29.72	31	29.76	35	29.90	31	Snow; ice still close, but evidently becoming melted.

Average daily mean, thermometer, 29°.33; coldest day, (1st,) 13°.00; warmest day, (3d,) 35°.33; cloudiness, 0.75; rain-fall, inch, 0.07; snow, inch, 0.08.

Meteorological register for Saint Paul's Island, Alaska Territory—Continued.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

MAY, 1871.

Date.	Thermometer.			Movements of atmosphere.									Amount of cloudiness.			Rain-fall.	Barometer and thermometer, attached.						Remarks.
				7 a. m.			2 p. m.			9 p. m.							7 a. m.		2 p. m.		9 p. m.		
				Winds.		Motion of clouds.	Winds.		Motion of clouds.	Winds.		Motion of clouds.											
	7 a. m.	2 p. m.	9 p. m.	D.	F.		D.	F.		D.	F.		7 a. m.	2 p. m.	9 p. m.		Barometer.	Therm'ter.	Barometer.	Therm'ter.	Barometer.	Therm'ter.	
1871.																							
May 1	25	32	26	N. W.	1	0	N. W.	1	S. E.	S. E.	1	S.W.	8	7	1	.00	29.94	29	29.99	36	29.95	32	Heavy ice packed all around the island.
2	31	34	30	S.	1	0	S.	1	0	N. E.	1	S.W.	8	8	8	.00	29.90	32	29.76	36	29.74	34	
3	31	29	24	N.	1	S.	N. E.	3	S.W.	N.	2	S.	8	8	8	.02	29.69	33	29.80	37	30.00	40	To-day, for the first time since Feb. 5, there is open water in sight to eastw'd.
4	28	34	28	S.W.	1	N.	W.	1	N. E.	W.	1	N.	8	8	8	.00	30.07	32	30.00	36	30.06	33	
5	33	32	29	S.W.	1	N. E.	N. W.	1	E.	W.	1	E.	8	5	8	.00	30.01	34	30.06	39	30.03	35	
6	30	34	31	E.	1	W.	E.	1	W.	E.	1	W.	8	8	8	.08	29.94	31	29.86	35	29.75	33	Rain.
7	34	34	33	0	0	0	S. E.	2	N. W.	S. E.	2	N. W.	8	8	8	.07	29.64	35	29.54	35	29.44	34	Rain.
8	34	40	32	S. E.	2	N. W.	S. E.	1	N. W.	S. E.	1	N. W.	8	3	8	.00	29.32	35	29.32	37	29.34	34	
9	38	38	25	S.W.	1	N. E.	W.	1	E.	N. W.	1	S. E.	7	8	8	.00	29.50	38	29.62	38	29.74	31	
10	25	28	24	N. W.	1	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	8	7	4	.00	29.81	31	29.84	34	29.85	35	
11	30	42	26	W.	1	0	S.	1	N.	0	0	0	1	8	0	.00	29.76	31	29.74	38	29.72	32	
12	33	34	29	S. E.	1	N. W.	S. E.	1	0	0	0	0	8	5	8	.00	29.70	33	29.71	38	29.68	31	
13	31	38	33	N.	1	S.	N.	1	S.	N.	1	S.	8	8	8	.00	29.74	33	29.76	38	29.75	34	Large bodies of ice in sight on both sides of the island.
14	33	33	32	N. E.	1	S.W.	E.	1	W.	N. E.	2	S.W.	8	8	8	.05	29.66	34	29.56	35	29.46	34	
15	32	33	31	N.	1	S.	N.	1	S.	0	0	0	8	8	8	.00	29.16	34	29.00	34	29.00	35	Ice all drifted to southwest.
16	33	41	34	N.	1	0	0	0	0	0	0	0	8	8	8	.00	29.94	35	28.96	41	29.00	36	
17	34	37	34	N.	1	0	0	0	0	0	0	0	8	8	8	.00	29.06	36	29.24	38	29.24	38	Foggy.
18	37	38	34	N.	1	0	N.	1	0	N.	1	0	8	8	8	.00	29.32	38	29.38	40	29.44	41	
19	38	41	33	N.	1	0	N.	1	0	N. E.	1	S.W.	6	4	7	.00	29.50	38	29.54	43	29.46	38	Rain.
20	33	34	34	N. E.	1	S.W.	E.	2	W.	S. E.	3	N. W.	8	8	8	.03	29.38	38	29.26	38	29.16	36	
21	36	38	36	N.	1	S.	0	0	0	0	0	0	8	8	8	.00	29.06	37	29.14	41	29.15	38	
22	39	38	36	0	0	0	S.	1	N.	S.W.	1	N. E.	8	8	8	.00	29.26	39	29.35	45	29.40	40	
23	40	48	34	S.	1	0	S.	1	N.	S.W.	1	N. E.	8	8	8	.00	29.56	40	29.64	48	29.78	36	
24	34	38	35	E.	2	0	S. E.	1	0	S.W.	1	N. E.	8	8	6	.09	29.05	37	28.90	40	28.80	39	
25	36	54	34	0	0	0	S.	1	N.	S.W.	1	N. E.	8	5	8	.13	28.70	38	28.91	47	29.18	40	Rain.
26	35	36	36	S.	1	N.	S.	2	N.	S. E.	2	N. W.	8	8	8	.10	29.15	38	28.93	48	28.75	38	Rain.
27	36	40	34	E.	2	W.	S. E.	1	N. W.	S.W.	1	N. E.	8	8	8	.07	28.65	38	28.71	41	29.85	38	Rain.
28	36	40	34	S.	1	N.	S.	1	W.	S.W.	1	N. E.	8	8	8	.04	28.95	42	29.06	40	29.10	37	Rain.
29	35	40	34	S. E.	1	0	0	0	0	S. E.	1	0	8	8	8	.10	29.18	38	29.28	42	29.30	37	Snow and rain in squalls.
30	36	41	34	N. E.	1	0	N.	1	S.	N.	1	S.	8	8	8	.07	29.34	37	29.28	42	29.28	37	Rain.
31	37	42	36	0	0	0	0	0	0	0	0	0	8	8	8	.13	29.42	38	29.52	43	29.51	40	Rain.

Average daily mean, thermometer, 34°.29; warmest day, (25th,) 41°.33; cloudiness, 0.93; rain-fall, inch, 0.98.

Meteorological register for Saint Paul's Island, Alaska Territory Continued.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

JUNE, 1871.

Date.	Thermometer.			Movements of atmosphere.									Amount of cloudiness.			Rain-fall.	Barometer and thermometer attached.						Remarks
				7 a. m.			2 p. m.			9 p. m.							7 a. m.		2 p. m.		9 p. m.		
				Winds.		Motion of clouds.	Winds.		Motion of clouds.	Winds.		Motion of clouds.											
	7 a. m.	2 p. m.	9 p. m.	D.	F.		D.	F.		D.	F.		7 a. m.	2 p. m.	9 p. m.		Barometer.	Therm'ter.	Barometer.	Therm'ter.	Barometer.	Therm'ter.	
1871.																							
June 1	38	40	36	N. W.	1	S. E.	N. E.	1	S. W.	N. E.	1	S. W.	8	8	8	.00	29. 40	40	29. 36	40	29. 28	38	7 a. m., light rain; 2 p. m., clear; 9 p. m., clear.
2	36	38	35	N. W.	3	S. E.	N. W.	3	S. E.	N. E.	2	S.	8	8	8	.13	29. 25	36	29. 34	38	29. 50	35	7 a. m., rain; 2 p. m., rain.
3	35	38	34	W.	2	E.	W.	2	E.	W.	1	E.	8	3	8	.10	29. 78	35	29. 96	38	30. 06	34	Clear.
4	38	41	33	W.	1	0	S. E.	1	0	E.	1	W.	8	8	8	.00	30. 20	38	30. 22	41	30. 10	33	Foggy.
5	32	36	35	N. E.	1	S.	N. E.	2	0	N. E.	1	0	8	8	8	.07	29. 92	32	29. 82	36	29. 74	35	Clear.
6	33	35	34	N. E.	2	0	N. E.	3	0	N. E.	3	0	8	8	8	.00	29. 59	33	29. 46	35	29. 36	34	Clear.
7	40	45	35	N.	2	S.	N.	3	S.	N. E.	1	S. W.	1	4	8	.00	29. 26	40	29. 24	45	29. 24	35	Clear.
8	39	49	38	N. W.	1	S. E.	N. E.	1	S. W.	N. W.	1	S. E.	8	7	8	.00	29. 28	39	29. 36	49	29. 36	38	Clear.
9	45	43	35	N. W.	1	0	N. W.	1	S. E.	N.	1	0	6	8	8	.00	29. 36	45	29. 32	43	29. 28	36	Clear.
10	39	55	37	N. W.	1	S. E.	N. W.	2	0	0	0	0	8	4	8	.00	29. 30	39	29. 36	55	29. 37	37	Clear.
11	41	42	46	N. W.	1	S. E.	N. E.	1	S. W.	N. E.	1	0	4	8	8	.00	29. 38	41	29. 70	42	29. 76	36	Clear.
12	44	52	38	0	0	0	0	0	0	0	0	0	7	4	8	.00	29. 76	44	29. 80	52	29. 84	38	Clear.
13	38	42	32	N.	1	0	0	0	N. E.	N. E.	1	S. W.	8	8	8	.00	29. 77	38	29. 72	42	29. 68	34	Clear.
14	45	47	38	N. E.	1	0	0	0	0	0	0	0	4	1	8	.00	29. 64	45	29. 70	47	29. 70	38	Clear.
15	41	47	38	N. E.	1	0	E.	1	0	E.	1	0	8	4	8	.00	29. 78	42	29. 74	47	29. 72	38	Clear and light shower of rain.
16	41	41	38	S. E.	1	0	S. E.	1	0	E.	1	0	8	8	8	.04	29. 20	41	29. 84	41	29. 72	38	
17	45	48	36	W.	1	E.	N. W.	1	0	N. W.	0	0	8	8	8	.00	29. 82	45	29. 84	48	29. 88	36	
18	48	54	38	N. W.	1	S. E.	W.	1	0	0	0	0	4	1	8	.00	29. 95	48	30. 00	54	29. 94	38	Light rain.
19	41	40	38	S. E.	1	0	S. E.	1	0	0	0	0	8	8	8	.10	29. 99	41	29. 84	40	29. 84	38	Light rain.
20	40	44	40	S. E.	2	0	S. E.	2	0	S. E.	2	0	8	8	8	.11	29. 82	40	29. 72	44	29. 66	40	Light rain.
21	39	39	38	S.	2	N.	S.	3	N.	S.	3	N.	8	8	8	.18	29. 50	39	29. 26	39	29. 24	38	Rainy.
22	40	50	39	S. W.	1	N. E.	S. W.	2	N. E.	S. W.	1	N.	8	2	4	.04	29. 66	40	29. 76	50	29. 84	39	
23	40	46	40	S. W.	1	N. E.	S.	1	0	S. W.	1	0	8	8	8	.00	29. 78	40	29. 76	66	29. 74	65	Fog.
24	38	46	35	W.	1	E.	S.	1	0	W.	1	0	8	8	8	.00	29. 74	60	29. 74	74	29. 74	70	Clear.
25	40	45	37	N.	1	0	N.	1	0	N.	1	0	8	8	8	.05	29. 70	64	29. 72	65	29. 72	65	Pleasant.
26	41	50	37	N.	1	0	N.	1	0	0	0	0	8	7	8	.00	29. 72	64	29. 73	67	29. 74	64	
27	39	44	37	N. W.	3	0	N. W.	3	S. E.	N. W.	2	S. E.	8	8	8	.00	29. 80	55	29. 82	64	29. 82	65	Showers.
28	40	41	37	N. W.	1	0	N. W.	1	0	S.	1	0	8	8	8	.10	29. 84	63	29. 84	67	29. 80	65	
29	40	42	33	N. E.	1	S. W.	N. E.	1	S. W.	N. E.	2	S. W.	8	8	8	.00	29. 82	63	29. 85	65	29. 85	56	Light rain.
30	42	46	38	N.	1	S.	N. W.	2	S. E.	N.	1	0	6	5	8	.11	29. 86	53	29. 87	57	29. 86	60	

Average daily mean, thermometer, 40°.20; coldest day, (6th,) 34°.00; warmest day, (18th,) 44°.66; cloudiness, 0.86; rain-fall, inches, 1.03.

Meteorological register for Saint Paul's Island, Alaska Territory—Continued.

[Latitude, 57° north; longitude, 170° west; height of barometer above tide-level, 40 feet.]

NOVEMBER, 1871.

Date.	Thermometer.			Movements of atmosphere.									Amount of cloudiness.			Rain-fall.	Barometer and thermometer attached.						Remarks.
				7 a. m.			2 p. m.			9 p. m.							7 a. m.		2 p. m.		9 p. m.		
				Winds.		Motion of clouds.	Winds.		Motion of clouds.	Winds.		Motion of clouds.											
	7 a. m.	2 p. m.	9 p. m.	D.	F.		D.	F.		D.	F.		7 a. m.	2 p. m.	9 p. m.		Barometer.	Therm'ter.	Barometer.	Therm'ter.	Barometer.	Therm'ter.	
1871.																							
July 1	45	45	38	N.	1	S.	N.	1	S.W.	N. E.	1	S.W.	8	1	2	.00	29.84	57	29.84	67	29.86	60	Clear.
2	44	44	37	N.	1	0	N.	1	S.W.	N. E.	1	S.W.	8	8	8	.00	29.86	57	29.68	54	29.86	60	
3	42	54	41	0	0	0	0	0	0	W.	1	E.	8	8	8	.07	29.86	58	29.86	66	29.86	65	Light rain.
4	43	52	42	S.W.	1	N. E.	S.W.	2	N. E.	S. E.	1	N. E.	8	8	8	.00	29.86	57	29.87	70	29.86	64	Clear.
5	43	52	40	0	0	0	W.	1	E.	W.	1	Fog.	8	8	8	.00	29.86	60	29.86	60	29.86	62	Fog.
6	41	42	41	0	0	0	E.	1	W.	E.	1	W.	8	8	8	.00	29.84	57	29.79	64	29.76	61	
7	39	41	39	N. E.	1	0	N.	2	S.	N.	2	S.	8	8	8	.18	29.75	59	29.68	55	29.68	60	Rain.
8	39	40	40	S.	1	N.	S.	1	N.	S.	1	W.	8	8	8	.07	29.69	57	29.72	65	29.76	63	Foggy.
9	41	41	40	S.	1	0	S.	1	0	S.	1	0	8	8	8	.03	29.90	62	29.91	60	29.90	63	
10	41	41	39	S.W.	1	Fog.	S.W.	1	0	S.	1	0	8	8	8	.00	29.92	63	29.92	63	29.92	66	Clear.
11	42	43	40	S.W.	1	Fog.	S.	1	Fog.	S.W.	1	0	8	8	8	.00	29.92	63	29.92	63	29.92	65	Clear.
12	41	44	41	S.W.	1	Fog.	S.	1	Fog.	S.	1	Fog.	8	8	8	.00	29.90	60	29.90	67	29.90	67	Clear.
13	40	52	40	S.	1	Fog.	S.	1	N. E.	N. W.	1	S. E.	8	4	8	.00	29.76	62	29.68	65	29.70	63	Clear.
14	48	49	38	N. W.	1	S. E.	S.W.	1	N. E.	S.W.	1	N. E.	3	3	8	.00	29.75	67	29.77	68	29.80	61	Clear.
15	45	56	44	W.	1	E.	0	0	0	S.W.	1	N. E.	5	5	8	.00	29.80	58	29.82	65	29.82	65	Clear.
16	46	49	39	S. E.	1	N. W.	S. E.	1	N. W.	S. E.	1	N. E.	8	4	7	.00	29.80	65	29.90	65	29.88	67	
17	42	50	41	N.	1	S.	N.	1	S.	N.	1	S.	8	8	8	.00	29.70	55	29.70	60	29.75	61	
18	44	47	42	0	0	0	S.	1	N.	E.	1	W.	8	8	8	.00	29.80	55	29.83	62	29.82	65	
19	40	45	41	0	0	0	S.	1	N.	S.	1	N.	8	8	8	.00	29.85	56	29.85	66	29.85	65	
20	45	48	42	0	0	0	N. W.	1	S. E.	S.W.	1	S. E.	8	5	8	.00	29.85	60	29.84	58	29.85	53	
21	44	46	41	N. W.	1	Fog.	N. W.	1	S. E.	N. W.	1	S. E.	8	8	8	.00	29.84	55	29.83	58	29.83	59	
22	44	48	43	N.	1	S.	E.	1	0	N.	1	S.	8	6	8	.15	29.83	55	29.83	66	29.83	67	
23	44	62	43	0	0	0	0	0	0	S.W.	1	0	8	6	8	.06	29.83	60	29.83	62	29.84	66	
24	43	44	42	0	0	0	E.	1	W.	N. E.	1	S.W.	8	7	8	.00	29.83	60	29.83	66	29.83	64	
25	42	42	41	N. E.	2	S.W.	N. E.	2	S.W.	N. E.	1	S.W.	8	8	8	.05	29.77	53	29.75	64	29.74	64	Rain.
26	41	43	42	N.	1	S.	N.	1	S.	0	0	0	8	8	8	.18	29.75	54	29.74	60	29.70	65	Rain.
27	43	45	42	0	0	0	S. E.	1	0	S. E.	1	0	8	8	8	.00	29.70	57	29.71	65	29.70	62	Fog.
28	43	44	38	S. E.	1	N. W.	S. E.	1	N. W.	0	0	0	8	8	4	.00	29.70	56	29.74	67	29.84	67	Clear.
29	41	51	41	S. E.	1	S.	S. E.	1	S.	0	0	0	8	5	8	.19	29.88	60	29.86	65	29.87	65	Clear.
30	47	46	42	N. E.	1	S.W.	N. E.	1	S.W.	N. E.	1	S.W.	8	8	8	.20	29.86	64	29.84	67	29.76	67	Clear.
31	47	46	44	N. W.	1	S. E.	N. W.	1	S. E.	N. W.	1	S. E.	8	8	8	.00	29.70	62	29.70	60	29.72	67	Foggy.

Average daily mean, thermometer, 43°.90; cloudiness, 0.92; rain-fall, inches, 1.18.

APPENDIX No. 8.

THE HARBOR OF NEW YORK: ITS CONDITION, MAY, 1873.

Letter of Prof. Benjamin Peirce, Superintendent United States Coast Survey, to the Chamber of Commerce of New York, with the report of Prof. Henry Mitchell on the physical survey of the harbor.

CAMBRIDGE, MASS., *May* 30, 1873.

DEAR SIR: The resolution passed in the chamber of commerce March 4, 1869, has been under careful consideration during the interval which has elapsed, and a continuous investigation of all the phenomena of New York Harbor has been conducted under the direction of Prof. Henry Mitchell, to whom the physical hydrography of the survey has been especially intrusted.

The inclosed report from Professor Mitchell illustrates the character and progress of the survey up to the present time. In it important numerical data are skillfully arranged, and in many cases exhibited in the forms of diagrams. All these data may be regarded as final as far as they go, and it should be especially considered that nothing in the report is speculative or merely theoretical. The paper is an embodiment of facts and observation. It is systematic experience, which is the most valuable as it is the most fruitful experience. The deductions are not from prejudice or unfounded fancy; they result from careful study and inquiry by men who are familiar with New York Harbor, and with the general laws of the dynamic action of waves, tides, and currents. The observers have sought the opinions of pilots, ship-captains, and engineers, and have neglected nothing which could conduce to a judicious conclusion. Wherever, therefore, injury to the harbor is specified, there can be no doubt that the proper remedy should be applied without unnecessary delay, and no undertaking can wisely be pressed in reference to the harbor that is manifestly opposite to the teachings of observation developed in this report of Professor Mitchell.

It will be observed that the Jersey Flats no longer receive the deposits formerly carried by currents upon its interior space. The extension of wharves, &c., at Jersey City have placed the flats under the lee, and the deposits now accumulate on the fore slope of the bank, so that the flats are rapidly growing out into the main channel. In large measure, these deposits are dredgings brought down from the city-docks and elsewhere, but some of the material found on them is still to be accounted for. Any scheme of occupation for these flats should provide specially for keeping the frontage bold, and the harbor-line should not lie far back from the present front of the flats.

In the vicinity of Middle Ground Shoal and of Gowanus a similar movement outward seems to have resulted from the artificial encroachments at Red Hook, but there the accumulation from foreign sources is small, and the changes observed have not been permanent.

There is no indication that the bar-channels have declined in any way. These will be reached by the survey last of all, unless something should appear to attract attention to them in advance.

The Lower Bay anchorage has changed, and this has been examined, but a further extension of work and close soundings are desirable there before results can be declared.

Mr. Mitchell's observations relative to the sub-current up the Hudson River develop the interesting fact that the flood predominates below six fathoms.

The depth on the bar is about equal to the seaward scour through the harbor, namely, twenty-two feet at low water; but this does not depend upon density, nor has it directly to do with dead angle.

Professor Mitchell gives good reasons for preferring *middle time* in the East River to the time of high or low water as that to be given to navigators: first, because it is less liable to fluctuation from accidental causes; and, then, it is nearer the time of the most rapid velocity, which is especially of importance to the sailor.

The whole amount of water which flows into New York Harbor in the course of each tide through the East River is sufficient of itself to raise the water of the harbor by one foot and one-tenth. If this flow from the East River into the harbor occupied the whole of ebb-time, it would increase by just this amount the outer flow through the Narrows and over the bar, and the ratio which this water bears to the whole outer flow would exactly represent the benefit of the East River in preserving the depth of water over the bar of the harbor. But this coincidence does not exactly occur. The ebb commences two hours before the turn of the tide in the East River, and during these two hours the flow is towards the East River instead of from it. Hence the amount of flow into the harbor must be proportionally diminished, and reduced to nine-tenths (0.9) of a foot. Now, the harbor at high tide has four and two-tenths (4.2) feet more of water in it than at low tide, which runs out during the ebb, together with the flow from the Hudson, which is about the same as that of East River. The whole of the flow, then, through the Narrows, which is independent of East River, corresponds to five and three-tenths (5.3) feet in elevation of the surface of the harbor, and this is the amount which would run if East River were to be cut off. The additional nine-tenths (0.9) of a foot which arises from East River gives a total of six and two-tenths (6.2) feet as representing the flow through the Narrows and over the bar. If the East River were cut off, the corresponding decrease in the flow of water would involve a proportionate decrease in the water-space over the bar, or a reduction of the depth of water upon the bar of about three feet and a half.* Such is the measure of the importance of East River to the preservation of the entrance to New York Harbor. The loss of this river would involve a fatal injury to the harbor, and any obstruction to its flow or reduction of its capacity must be proportionally injurious.

Believing that the accompanying report embraces the principal points which deserve immediate attention, it is respectfully presented for the consideration of the chamber of commerce, and I hope that it will be considered to deserve immediate publication.

Yours, respectfully,

BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

GEORGE W. DOW, Esq., *Chairman.*

REPORT OF PROF. HENRY MITCHELL.

MAY 6, 1873.

DEAR SIR: The physical survey of New York Harbor and its approaches was resumed in 1871, and has made, during the past two years, considerable progress, so that some results can be stated quite safely. The immediate occasion of the resumption of these inquiries was a resolution of the New York Chamber of Commerce, dated March 4, 1869, calling upon you to consider "an apparent change going on in the formation of the harbor of New York and its entrance, which, if not soon attended to and corrected, threatens to be productive of very great injury." You, in reply, named Capt. C. P. Patterson and myself as your associates in the study suggested, and asked for a committee of conference, which was at once appointed by the chamber, and has been retained up to this time. This arrangement has been a great advantage to me, since it has given me, in field-operations, a claim upon your special interest and the co-operation of Captain Patterson. I have also felt free to consult Mr. Dow and Mr. Blunt (of the committee) from time to time, and thus the work has been more closely confined to practical objects and wants than it was in our first attempt fifteen years ago.

You will not, of course, expect, in this progress-report, any general discussion; I am, in fact, not prepared for this, but I shall take up certain shoals and channels and state facts regarding their changes and conditions of existence as far as we have learned.

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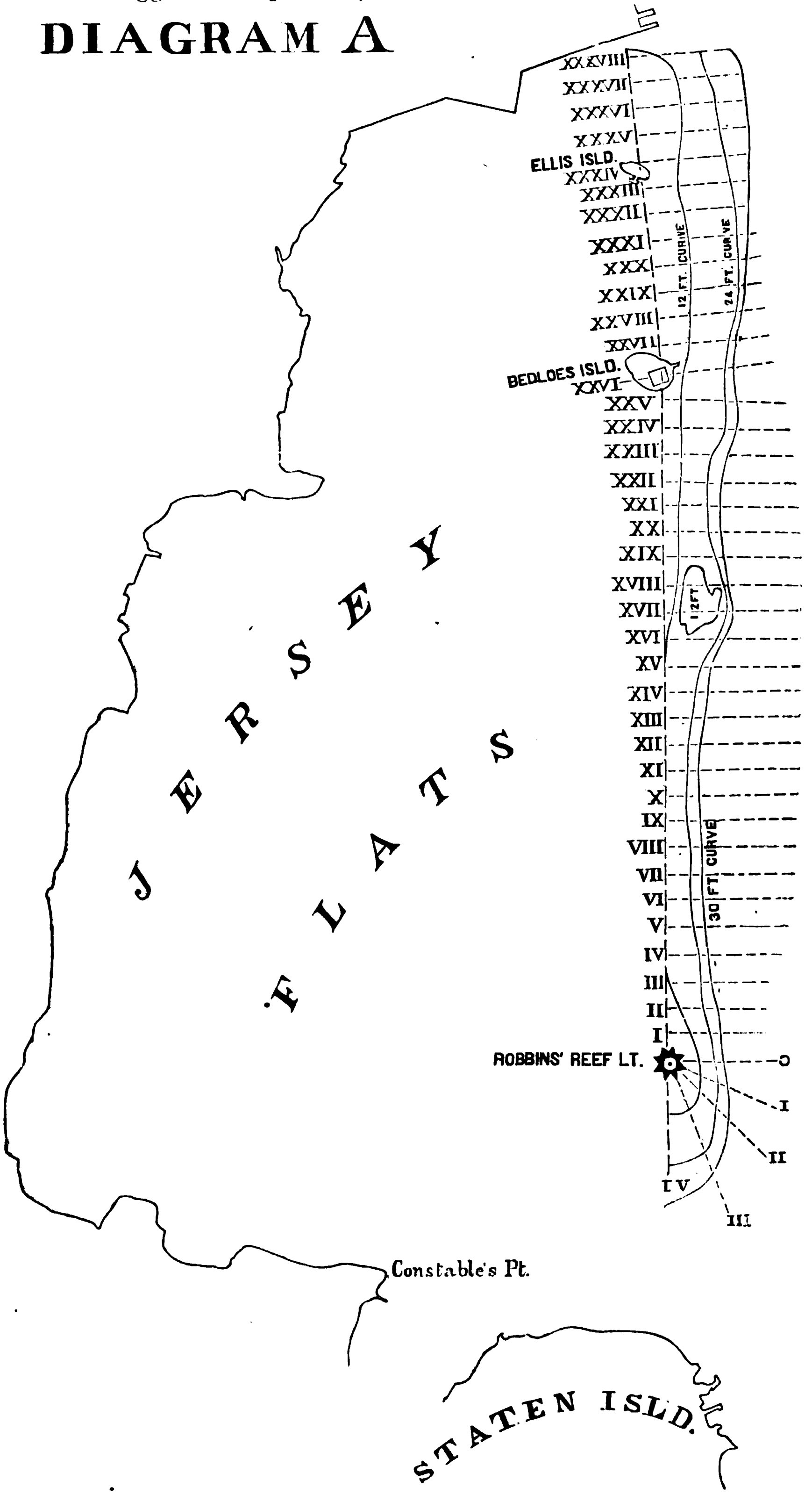
* This is a result of a simple application of the rule of three. The reduction of the depth upon the bar must bear the same proportion to the mean depth of 24.2 feet which the diminution of the flow of water represented by 0.9 bears to the whole flow represented by 6.2; *i. e.*, the reduction must be a little more than one-seventh part, or, more exactly, 3½ feet, for the water-way must evidently correspond in magnitude to the amount of water which flows through it.—B. P.

Changes for the worse being the most important, I shall commence with them; but in order that our facts may not produce an exaggerated impression, I feel that it is necessary to say beforehand that no evidence of a *general deterioration of the port* has yet appeared, and that we need apprehend nothing of the kind if wise counsels prevail in future.



INCREASE OF JERSEY FLATS.

In the autumn of 1872, the survey of Jersey Flats was completed by Mr. Marindin and his party, and the figures given in the appended tables are those resulting from a comparison of the recent survey with that of 1855, which has been replotted at Washington under the special care of Captain Patterson, who has advised with us in these surveys from the first.

The plan of comparison we have pursued has been as follows: A line has been drawn upon our field-sheet from Robbin's Reef light-house to Bedloe's Island flag-staff, thence (slightly deflecting) through Ellis's Island flag-staff to the New Jersey Cenrtal Railroad wharf. This datum-line lies above all marked changes, and is so placed as to fall nearly parallel to the border of the flats, so that ordinates from it are essentially normals to the characteristic contours upon the bank of the main channel. We have drawn 38 of these normals between Robbin's Reef light and the Central Railroad, at distances of 500 feet; and at the turn into the channel leading to the kills we have constructed radii from the light-house as a

center. Upon these normals we have measured the changes in the positions of the 6, 12, 18, 24, and 30 feet curves since 1855, and stated our results numerically upon Table 1. This first table shows the advance or retreat of the contours at the points where they are intersected by the normals. You will observe that all the curves have been pushed outward since 1855, but most conspicuously the 24-feet curve, which in the average has moved out 303 feet, and at the maximum 825 feet. By just so much the main channel of the harbor, for heavy ships, has been reduced in width. The extreme reduction stated, however, equals only one-sixth part of the former width of the channel.

In this neighborhood deposits of material dredged from the city-docks and elsewhere had been deposited for many years previous to 1871, when, at our suggestion, the Pilot Commission declined to grant the privelege of further deposits. As I understand the matter, this commission had designated, as a site for deposits, the deep waters of the main channel off Oyster Island, where our printed map showed depths of over 10 fathoms. Whether or not the parties who dumped the material were careless of their whereabouts, and found it more convenient to drop their loads on the border of the flats, we are not advised; but we feel pretty sure from the aspect of the case that the great shoaling in this place is artificial. The greatest elevation of deposit since our survey of 1855 is 31½ feet, reducing to 4 feet depth a portion of the main ship-channel where some seventeen years before the Great Eastern could have passed with 250 feet between her and the 30-feet curve. The foregoing is an extreme case, of course, but we are able to state that the flats, throughout the entire distance from Robbin's Reef to nor mal XXXIII, a distance of over three statute-miles, have grown out into the main channel to the injury of navigation. Some excavations, and deposits incidental to these excavations, seem to have disturbed the order of things between Ellis's Island and the Central Railroad wharf, so that no general statement can be safely made concerning the change in the area of the flats in this neighborhood. If we regard the 24-feet contour as being the true border of the flats on the side toward the main channel, we may state the increase of the shoal-ground to be 129 acres.

Next in magnitude of change, and most important from a commercial point of view, is the outward movement of the 18-feet curve, which amounts in the average to 211 feet, and represents over 92 acres. Upon normal XVII, (the dumping-ground above referred to,) the maximum movement outwards is 930 feet, and upon adjacent normals, on either hand, 710 feet. The 12-feet curve has advanced to a still greater extent on normal XVII, where it is found to be over a thousand feet farther out than in 1855!

The 6-foot curve is so near the general plane of the surface of the flats that its movements are on the whole uncertain and insignificant. All the movements stated above are those which have taken place outside (seaward) of the axial line from which our normals are drawn; within this line the nearly horizontal surface of the flats has remained essentially the same where unoccupied.

At the point of the flats near Robbin's Reef, the border of the shoal-ground has retreated over a hundred feet, except along the 12-feet curve, where little change has occurred. (See Table No. 2.)

In Table No. 3 I have furnished in detail the areas of change upon planes of 6, 12, 18, 24, and 30 feet depths at low water.

Finally, in Table No. 4, I furnish the volumes which have been added since 1855. You will observe that nowhere along the front of the flats has there been any *loss*, but in every reach of a thousand feet a considerable *gain*—not less than 1,540,000 cubic feet anywhere.

The total deposit upon the border of the main channel, since 1855, is 76,859,250 cubic feet, or 2,846,640 cubic yards. To dig out this mud again, and carry it where it could be of no possible harm, would cost nearly a million of dollars. This is rather a startling disclosure when you consider the narrow belt that our figures cover. It is, however, less alarming than the result of the previous comparison made by the advisory council to the New York Commissioners on Harbor Encroachments, in 1855–'57; but it is *more certain*, because we have the survey of that council for our basis, and have proceeded as carefully ourselves in repeating the survey.

That council pointed out as a cause of deposits the unwise extension of piers at Jersey City, but their warning voices were unheard or unheeded. As I have stated, much of the recent deposit appears to have been artificial, but there is enough unaccounted for to warrant an appeal to the State of New Jersey to adopt measures for preventing unwise encroachments hereafter.

CHANGES IN BUTTERMILK CHANNEL.

In my report of last year, printed by the Pilot Commissioners, as an appendix to your letter to the president of the board, bearing date of February 16, 1872, I described the results from a comparison of surveys made in Buttermilk Channel, and over the shallow ground southward of Governor's Island. The only striking point stated was the diminution of depth on the summit of the shoal at the eastern entrance of this channel. Captain Patterson has discovered, in overhauling the records, that a sounding of 9½ feet was made on this very spot in 1855, and omitted from the plotting, perhaps intentionally, after diligent search for the place had failed to repeat the observation. It is a very small knoll, and therefore difficult to find.

CHANGES IN THE VICINITY OF MIDDLE GROUND SHOAL AND GOWANUS BAY.

The eastern side of the harbor, below the Atlantic Docks, was resurveyed during the past season by Mr. F. F. Nes, and his party of the steamer Arago. The funds for this work were mostly supplied by the Commission on Pier-Lines, for whose use our chart was made; but we have instituted a close comparison between this survey and the one of 1855. The method of comparison which I have adopted in this case, and shall describe below, differs from that employed for Jersey Flats, you will perceive, and you will easily see that in each case it is intended to make prominent the *character* of the change. In one instance a flat is growing out into a deep channel; in the other the bottom is shifting. In the former the horizontal area and the volume are most important; in the latter the vertical changes of depth attract our attention.

Upon our field-sheet we have drawn a straight line from the city-hall, tangent to Red Hook, which terminates at Bay Ridge flag-staff. This line, which we may consider the outer chord of Gowanus Bay, we have made our axis of ordinates, and drawn these ordinates at intervals of 500 feet. We have also drawn parallels to our chord at distances of 250 feet, and at the points where these cross the ordinates we have determined the changes of depth, and stated the same in Table No. 7, and Diagram B. It was only by thus cutting up the ground into equal spaces that we could ascertain with any certainty the total deposit from foreign sources, and distinguish between *accumulation* and *shifting*. The general result is a shoaling, which, on the harbor-side of our chord, is in the average only a quarter of a foot, and in Gowanus Bay, exclusive of the Erie Basin, less than a half-foot. The Erie Basin itself, notwithstanding considerable dredging, is in the average 0.61 foot shoaler now than in 1855.

Referring to this diagram you will discover that there has been a deepening off Red Hook, which we follow along the chord of the bay, and down two parallels on either side of this chord, *as if a stream had swept round Red Hook and across the opening of the bay, washing away the bottom irregularly.* It may be that the completion of wharves, extending from Red Hook, has quickened the stream from above a little, and changed somewhat its direction. You will remember that I reported to you some time since the causes of the Middle Ground as observed, and predicted that if Red Hook were extended this shoal would move out. I had not then made the comparison, and was not aware that any movement of importance had really taken place. You may trace in the groups of figures outside of the shoal upon our diagram a decided movement towards the main channel, and at the foot of the shoal the growth to the southwestward is striking.

The lower mouth of the Middle Ground Channel, off Bay Ridge, seems to have had a shifting bottom, but no harmful change has taken place in this neighborhood. The bar of this channel, which lies between normals XVII and XXII, and between parallels 500 and 2000, (see Diagram B,) has shoaled nearly a foot in the average, and there are places upon it which have 3 an 4 feet less water than formerly.

Within the Erie Basin, and at its northern entrance, artificial changes appear; and notwithstanding that much dredging has been done, the shoaling is in decided excess of deepening.

CHANGES AT AND NEAR THE SANDY HOOK ENTRANCE.

Our resurveys have been confined thus far to localities where changes are reported or suspected, and the Sandy Hook Basin has been under examination with some interesting results,

but until we can so extend the work as to comprise a wider range than that covered by the hydrography of Mr. Nes last autumn, I do not feel ready to discuss this part of my subject.

I presume Mr. Nes will join me again the coming season, and complete this work. The west side of the Lower Bay, as far as examined in our surveys for the Department of Docks, had undergone no change worth mentioning.

TIDES AND CURRENTS.

Although I have not yet made all the observations requisite for a complete view of the tidal phenomena in the harbor and approaches of New York, I have reached that point where I can exhibit my results in tables complete as far as they go, and therefore I have thought best to ask you to accept these data, and have them printed, that they may be accessible to those persons whose public or private interests lead them to follow us in these inquiries.

I shall commence by introducing tables showing at what interval after the transit of the moon the strength of the current occurs; I call this the *lunar-tidal interval of middle time*, because I do not use the time of the highest velocity recorded, but the middle of the curve (for flood or for ebb) given by all the velocities carefully plotted. This plan suggested itself to me when working on the currents of San Francisco, where the diurnal irregularities are very large and the effects of freshets and prevailing winds very considerable. I concluded that, because the diurnal irregularities in the intervals of high and low water have different signs, the time of any intermediate phenomenon (like maximum velocity) must be more or less free of this inequality. Moreover, I concluded that the maximum velocity would occur at the same time whatever constants might enter, so that in great measure this time would be unaffected by regular winds or continued river-floods. In the case of San Francisco, my computations came out indifferently, but in treating New York the advantage of using middle time instead of slack-water is very decided. My method is illustrated in Fig. 1 of Diagram C, in which the observed curve is plotted in full line, while the chords and the axis are given in dotted lines.

The mean time of the axis (which is a line drawn downward so as to bisect all the chords) is what we call the "middle time." You will observe that this element is dependent upon all the observations, and not upon one or two, which might be the very ones affected by irregular causes. Table No. 8 contains the numerical data from which the first figure upon our sketch is plotted; and Tables Nos. 9, 10, 11 furnish all the principal elements of the tides and tidal currents. Tables Nos. 9 and 11 furnish the results from actual observations, while Table No. 10 is a recapitulation of Table No. 9, *adjusted* and extended. This adjustment is effected by plotting the observed results, and drawing through the figures smooth curves, which are supposed to strike out only those irregularities which have been due to strictly local peculiarities and errors of observation. The vertical tides, *i. e.*, the *rise and fall*, have required very little adjustment, because, being observed for long series, they give, from averages, a smooth curve. Our manner of observing the vertical tide by recording the times of high and low water, and referring these to the moon's transit, is far less certain of giving the truth from short series of observations than our method of using middle time in the case of currents, or even the use of slack-water intervals; but the convenience with which the rise and fall of the tide can be observed enables us to repeat observations till the mean results come very near to the truth.

To the adjusted table (10) we have added columns of deflections, depths, sections, perimeters, mean radius, &c., all the elements which might be expected to vary the tidal phenomena.

Speaking in a general way, the delay of tidal epochs from point to point may be said to increase slowly as we go up the river, while the delay of the current epochs decreases rapidly.

PHENOMENA IN THE PATHWAY OF THE HUDSON.

In Table No. 12 we have given the velocities of the currents at different depths below the surface at our principal stations in the pathway of the Hudson River; and in Diagram C we have plotted the results for alternate lunar hours, so as to exhibit the changes from the Narrows to Forty-first street.

You will observe from this table (12) and Diagram C that over the bar the greatest velocities near the bottom are reached during the ebb, but that at and above the Narrows the flood seems to predominate over the ebb *along the channel-beds wherever the depth exceeds six fathoms.*

In reports some years ago, I called your attention to the fact that for several consecutive hours we have at the mouth of the Hudson a comparatively fresh stream running seaward upon the surface, and a salt stream taking the opposite course below. I conceived that in the months of summer, the season of our work, the head of the river so declines that it cannot balance the sea-water, which consequently flows in along the bed. During the past two seasons we have taken pains to measure densities, and have traced the sea-water along the channel-bed as high up as Carthage, seventy miles from Sandy Hook; but the surface-water was found essentially fresh at Teller's Point, forty-three miles from Sandy Hook.

There is a native oyster found in the Tappan Sea, which is too small for the market, but is a favorite for planting elsewhere, and it was reported to us that oysters had also been found in Haverstraw Bay, and sea-crabs as high up as Carthage, ten miles below Poughkeepsie.

In Table No. 13 we give the specific gravities, observed at the different stations, corrected for temperature by Hälström's rule. These data were collected by Mr. Marindin, while our current observations were in progress in the year 1871. The water was pumped up through pipes, so that no mixtures of different strata affect our table.

The density of the sea on the chord of the great bay, which lies between Nantucket and the capes of the Delaware, was observed by me in 1867, and found to be 1.024 at the temperature of 60°. This may be set down as the normal density of the Atlantic in the *approach* to our coast, while yet beyond the direct influence of our rivers. In the year 1865 we made some observations upon temperature and density between New York and Cape Cod by the inland route, finding in the Race a density of 1.0224, and outside 1.0233, which density was carried through the Vineyard and Nantucket Sounds. Observations of 1871, in the Race, gave us a density of 1.024.

It appears from our table (No. 13) that in the portion of the Hudson bordering on New York City there is no great contrast of densities between the top and bottom of the sea, although it is decidedly marked at Twentieth street at the close of the ebb-current. Above this point there is a rapidly-increasing variation of density with the depth for the close of the flood-current; but the close of the ebb-current presents little contrast of densities until we get above Dobb's Ferry, or well into the Tappan Sea. At Teller's Point, which lies between the Tappan Sea and Haverstraw Bay, the differences of density between surface and bottom are very great. It would seem that these great basins store up the sea-water somewhat, as does the Mystic Pond, at the head of Mystic River, above Boston. (See special report of United States commissioners on Boston Harbor, published in 1861.) The great basins terminate, essentially, at Verplanck's Point, where the difference between surface and deep waters is conspicuous only on the flood. Above this point all contrast declines, and, finally, at Barnegat, seventy-five miles from Sandy Hook, the river is of uniform density at all depths, being essentially fresh.

Although no critical comparison can be made between the different stations represented in Table No. 12, because the observations were not simultaneous, and have not been corrected for half-monthly inequalities, yet we may venture to suggest that at the depth of 22 feet at low water—which is that of the bar-channel—there is still ample seaward scouring-force all along the line; that the bar does not lie in the dead angle between the salt and fresh water, but, in its general character, belongs to the same class as those at our southern inlets; in other words, it is a broken part of the *littoral cordon* of sand that skirts the coast, and is kept open in this case by the tidal circulation, which I have referred to in previous reports as the "*life-blood of the harbor.*"

MOVEMENTS THROUGH THE EAST RIVER.

In Table No. 11 we have given the tidal elements of the East River and its approaches. These elements are from actual observations, which we have not attempted to "adjust," as in the previous tables. The currents of the East River, from the southern entrance of Buttermilk Channel to Throg's Neck, belong to the *interference* system, which I have discussed in my report on Hell Gate,

Appendix No. 13 of the Coast Survey Report, published separately in 1869. I find it necessary to quote a few paragraphs from this report, in order to illustrate my subject, and explain in what manner this table (No. 11) differs from those previously given for the Hudson:

"New York Harbor is visited by two derivations from the tide-wave of the ocean, one of which approaches by way of Long Island Sound, the other by way of Sandy Hook Entrance. These two tides meet and cross, or overlap, each other at Hell Gate; and since they differ from each other in times and heights, they cause contrasts of water-elevations between the Sound and the harbor, which call into existence the violent currents that traverse the East River.

"In the course of our laborious tabulations of the data from my physical surveys of 1857 and 1858, it has become apparent that the general order or scheme of the tidal interference is very simple, and that the apparent complications result from the mingling of local peculiarities; for this reason I deem it essential to offer a general view of the scheme, denuded of all its details, before inviting you to follow through tables and diagram to the phenomena actually observed.

"If the entrance from the Sound were closed at Throg's Neck, the tide which comes in over the bar would prevail all over New York Harbor, and we should have on the west side of Hell Gate a tide of 4½ feet range, with its time of high water about one-half hour later than at Sandy Hook; *i. e.*, eight and a half hours after the southing of the moon. In passing through the gate and spreading out upon the broader spaces beyond, this tide would essentially lose its wave character, and become very much reduced in range, so that at the Brothers Islands it would be scarcely sensible.

"If, on the other hand, the Sound entrance were to remain open and the Sandy Hook Entrance be closed, a very different order of tides would prevail. On the east side of Hell Gate the tide would have a range of about seven feet, and high water would occur there about twelve hours after the moon's transit. In passing the gate, it would suffer degradation, but not very rapidly, till it had advanced beyond the Blackwell's Island channels. In the basin of the upper harbor, however, it would become very small, and essentially waste itself and disappear in the lower harbor. If these two suppositions are correct, we ought, with both entrances open, to find at Hell Gate a tide, whose times and heights are intermediate between those now observed at Sandy Hook on the one hand, and Throg's Neck upon the other; while at other points the proportions would be unequal, according as our place of observation was more distant from the meeting-point on either side.

* * * * * * * * *

"Premising that *all currents are caused by disturbances of the surface-level*, we may see, without effort, that in harbors visited by a single tide-wave, (not materially distorted in its figure from point to point,) *slack current* must follow the *stand* of the tide, since at this time the surface-level is restored. Again, for this single tide, the maximum velocity must occur near the time of half tide, because at this time the greatest rise or fall, and consequently the greatest filling or draining, is taking place. In the neighborhood of Sandy Hook, or at Throg's Neck, the currents do follow, in the manner we have stated, the local tide; but in the East River, where two tide-waves approach from opposite directions, the changes of surface-level, and consequently the currents bear no direct relation to either tide-wave considered by itself, but depend upon the nature of the 'interference,' as it is called. * * * * * * * * * * * *

"These differences of surface-level are the vertical measures of the slopes—tidal *heads*, if we may use this term so loosely—and they increase from zero to maximum (4.87 feet) in about three hours; then decline to zero in about the same time. * * * * * * * *

"The following summary of the leading points which I have attempted to illustrate will serve as my guide in the arrangement of my observed data:

"First. Two tide-waves visit New York Harbor, meeting and overlapping at Hell Gate.

"Second. Near the meeting-point of these two tides, the observed heights and times of the compound tide are intermediate.

"Third. The currents of Hell Gate are called into existence by the variations in the relative heights of the Sound and harbor; their epochs have no direct relations with those of the local tide or its components, and their velocities do not depend upon the local rates of rise or fall of tide.

"Fourth. The current flowing westward through Hell Gate occupies a greater section than

that flowing to the eastward, because the former prevails during higher stages of the local tide than the latter."

The third point made in the above quotation seems to be confirmed, because we find that subtracting the observed tides on the east side of the gate from those observed upon the west side, we have maximum differences of level at 6^h 41^m and 12^h 13^m after the transit, and the maximum velocity of the tidal currents at the north end of Blackwell's Island (see Table 11) at 6^h 30^m and 12^h 38^m. When we consider that these differences of level and times of maximum velocity are modified by so many local circumstances, the reaction of numerous reefs, the passing of great fleets of vessels, the winds, &c., I think the above agreements are about as near as we could expect from short series. If we had observed long series of tides at Throg's Neck and Governor's Island, which we did not, I have no doubt we should have come much closer. Mr. Striedinger, an assistant to Major-General Newton, who has leveled very closely through the gate, tells me that the local disturbances are very considerable as reflected in the varying slopes.

We may, without material error, use the following rule for the East River current: *The strength of the flood-current occurs six hours and a half after the transit of the moon, and the strength of the ebb-current at twelve hours and a half after the same transit*, (or about twenty minutes after the immediately preceding transit.)

The above rule at neap-tides will cover the axis of the entire channel from Atlantic Dock to Throg's Neck, but at spring-tides would extend easterly only as far as Old Ferry Point.

Current observations at the Race were made, but under circumstances not altogether favorable, and those for points below the surface I have rejected as far as velocities are concerned, because I am convinced that the stray-line (whose out-run is designed to permit the lower log to sink to the full length of the connecting wire, before the observer begins to count) was not in this case long enough, so that added to the real velocity is the descent of the log in part. Our vessel was anchored in 40 fathoms of water. Concerning the tides and currents of Long Island Sound, Mr. Schott has written a paper in the Coast Survey Report of 1854.

In Table No. 14 we furnish the observations made at several stations simultaneously in a line across the East River at Wall street. The velocities given are those observed at the surface, but a pretty thorough examination was made of those below the surface without revealing any changes which we could connect with the lunar hours.

By reason of the delay of the tide through the East River, the relations of flowage to section differ from point to point. While at Hell Gate the greater section is that of ebb, (westerly flow,) the greater section at Wall street occurs during the flood, (easterly flow.) You will learn from Table No. 15, which is made out from very careful data—comprising velocities at different depths, at different distances across the stream, and at different times—that the section during the flood is 91,560 against 86,960 square feet during the ebb. The volumes passing in the two directions are much the same. The small difference which appears in the table is probably due to errors in reduction. The mean movement is that of 4,362,300,000 cubic feet in either direction. If a canal of the same width and section as the East River at this point were extended without limit, and visited, like the Hudson, by one tide only, no such movement as this could be generated—this is a matter of computation—so that the phenomena we have observed are those peculiar to the co-existence of *two inlets* traversed by *different tides*. The strong currents in the pass between Martha's Vineyard and the main-land in the neighborhood of Vineyard Haven, where the channel is over three miles wide, and more than 60 feet deep in the average, are due entirely to the *interference* of two tides differing, like those that visit New York Harbor, both in time and range.

EAST RIVER AND HUDSON TIDAL CURRENTS COMPARED.

Table No. 16 gives in detail the soundings and positions of stations in two cross-sections, one of which was in the East River, and has been commented upon, the other in the North River at Forty-second street.

Table No. 17 contains our observations at Forty-second street in full, together with a recapitulation of the velocities arranged according to lunar hours, and corresponding to table No. 14. These observations are illustrated upon Diagram D, in explanation of which I shall offer a few comments. The curves are those for surface-velocities, and do not represent the movements for all

depths. Those above the axis are plotted from flood-velocities, which take a northwardly direction in the Hudson, and an easterly direction in the East River; while those below the axis are reverse courses. In the first figure of this diagram the abscissas are hours of civil time, but in all the others they measure distances from the west shore. In Fig. 1 it will be observed that the ebb is everywhere in excess of the flood, but most conspicuously so in the middle of the river, and least so upon the western shore, where the two drifts approach equality. These curves indicate that middle time as well as all other elements vary in the transverse section, and that some of the irregularities which appear in Tables 9 and 10 are due to the circumstance that our stations were not always located in the axis of the stream.

Passing on to the transverse curves you will observe that for nearly three hours, between III and VI hours, after the transit the ebb of the Hudson may be supposed in part to flow towards the Sound; while the East River ebb is a tributary of the Hudson flood for scarcely two hours, between IX and IX hours. You will bear in mind that the terms "flood" and "ebb" as applied to the East River streams are merely used in their popular sense. The general inference from the above statements would be that the East River is an outlet and feeder of the Hudson for several hours of each day.

RELATIONS OF EAST RIVER MOVEMENTS TO THOSE OVER THE BAR.

Computations made upon the observations at different depths in 1858 gave for the discharge of the Hudson at the close of the wet season, (1st June,) 6,038,000,000 of cubic feet, and at the close of the dry season, (September,) 3,360,000,000. Our more extended observations of 1872 (October) give nearly equal inflows and outflows, amounting to 4,511,000,000, which is about the mean of the two gaugings of 1858. Now, this added to the ebb-volume of the East River, which was 4,383,000,000, gives 8,894,000,000. If to this we add the harbor tidal prism, 17,862,000,000, (which includes Newark and Raritan Bays and the Kills,) we have 26,756,000,000 of cubic feet. The gauging across the mouth of the harbor from Sandy Hook to Coney Island gave, from observations of 1858, an outflow of 27,663,000,000 of cubic feet, which is only about 2½ per cent. more than the preceding computation. Perhaps this little excess is due to the discharges of streams and creeks not considered in the previous computation, because not gauged. I confess that I had expected a much greater excess, because I had not counted in the Passaic, Hackensack, Raritan, and Shrewsbury Rivers, from which considerable volumes, even in the dry season, must escape by way of Sandy Hook and by way of Hell Gate. Without claiming that *all* the water that comes in through the East River goes out over the bar, and aids in the scour of its channel, I think this computation authorizes us to regard the East-River stream as too important to be treated lightly.

I think you have fully explained the entire discrepancy between the views expressed by Mr. Dow and those which we have based upon our observations, in pointing out that Mr. Dow is reasoning upon the supposition of a harbor visited by a single tide entering simultaneously by two mouths. If this supposition were correct, *i. e.*, if the same tidal undulation came up from Throg's Neck and in over the bar at the same time, the office of draining and filling the harbor and river with tide-water would be divided between the two outlets, and the currents of flood and ebb would be much weaker than now through these outlets—much weaker, in such a case, with two outlets than with one, of course. But as a matter of fact, the order of things is quite different from these supposed cases. The tide coming in at Sandy Hook not only has to feed New York Harbor, but for a while the Sound also; and, *vice versa*, the water flowing in from the East River not only has to feed the harbor and its rivers, but the ocean outside of Sandy Hook (being for several hours at a lower level than the East River) receives the drainage of the Sound in addition to that of the harbor. In this way New York Bar is crossed in either direction by a volume of water considerably greater than the simple filling and emptying of New York Harbor and its rivers would demand. If you were to close the East River by a dam, you would reduce both flood and ebb currents on the bar very sensibly, because, as we have seen, several millions of cubic feet would be cut off, which now traverse the seaward channels four times a day.

I must add one general statement concerning a harbor with two or more outlets. It does not follow, even when such a harbor is visited by only one tide, that there is a disadvantage in having more than one pathway to the sea. On the contrary, a majority of the first-class harbors of the world

have several. Among sands it is not wholly upon the strength of the current that *effective* scour depends, but upon the power of these to dispose of the material advantageously. Equal and opposite tidal currents, however strong, cannot remove the bars of our southern inlets, because in the short period of six hours the very slow *dune-like* movement of the sand has not carried it beyond the influence of the adverse stream with which it works back to its old place; but where the ebb and flood are unequal, the material is swept entirely away from the mouth of the harbor. Now, with harbors of two outlets, it often happens (and I speak here with plenty of observed data at my command) that one channel is more favorably situated for discharge than the other, so that, in *effect*, there is a circulation *in at one door and out at the other*. It is precisely for the sake of inducing such a circulation that a second outlet is now being constructed from a sandy harbor on the west coast of Denmark.

One may presume that if there were no tides at all in New York Harbor, the two openings would be of advantage to each other. In a northeast gale, for instance, the Sound waters, driven before the wind, mount up several feet at Hell Gate, and would rise much higher except that they escape through the harbor of New York, and out to sea over the bar. In this case the entire Sound is useful, because it is a shallow sea in which the effect of the wind is largely *translation* instead of *oscillation*, (as in the ocean.) The wind cannot blow from any quarter without disturbing the balance of the two outlets, and this disturbance is represented in effective scour at the bar.

Very respectfully, yours,

HENRY MITCHELL.

Prof. BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

List of tables accompanying report of Prof. H. Mitchell on New York Harbor, 1873.

No. 1. Advance and retreat between Robbin's Reef light and the Central Railroad wharf.
No. 2. Same round the point of the flats.
No. 3. Horizontal areas.
No. 4. Volumes.
} Changes on the Jersey Flats.

No. 5. Depth of water in 1855.
No. 6. Depth of water in 1872.
No. 7. Changes of depth between 1855 and 1872.
} Changes in the vicinity of Gowanus Bay.

No. 8. Currents of Gedney's channel.
No. 9. Tides and currents in Hudson River and approaches.
No. 10. Tidal elements of Hudson River, adjusted.
No. 11. Tides and currents in East River and approaches.
No. 12. Currents at different depths in the Hudson and New York Harbor.
No. 13. Specific gravities of water in the Hudson.
No. 14. Currents of East River at Wall street.
No. 15. Volumes passing through East River at Wall street.
No. 16. Mean low-water sections at Forty-second and Wall streets.
No. 17. Currents of Hudson River off Forty-second street.

List of Diagrams accompanying report of Prof. H. Mitchell on New York Harbor, 1873.

B. Showing changes in the vicinity of Gowanus Bay.
C. Showing vertical-current curves; also method of computing "middle time."
D. Transverse curves of velocities in the Hudson and East Rivers.

TABLE No. 1.—*Changes on the Jersey Flats, New York Harbor, as shown by the surveys of* 1855 *and* 1871–'72.

Number of normal from Robbin's Reef light.	Distances from the datum-lines of the 6, 12, 18, 24, and 30-feet curves.															Depths along the datum-lines.		
	6-feet curve.			12-feet curve.			18-feet curve.			24-feet curve.			30-feet curve.					
	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Difference.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	......	......	......	495	630	+ 135	825	905	+ 80	930	1,065	+ 135	1,160	1,165	+ 5	0	0	± 0
I	......	......	......	290	515	+ 225	570	850	+ 280	650	970	+ 320	1,115	1,075	− 40	8¼	8	− ¼
II	......	......	......	175	335	+ 160	380	750	+ 370	585	880	+ 295	975	1,020	+ 45	10	9½	− ½
III	......	......	......	90	165	+ 75	275	520	+ 245	550	850	+ 300	850	935	+ 85	10	10¼	+ ¼
IV	......	......	......	0	40	+ 40	200	285	+ 85	410	700	+ 290	800	900	+ 100	12	11¼	− ¾
V	......	......	......	......	......	......	150	210	+ 60	460	570	+ 110	775	900	+ 125	14	13	− 1
VI	......	......	......	......	......	......	100	170	+ 70	400	575	+ 175	825	825	± 0	15	13	− 2
VII	......	......	......	......	......	......	60	175	+ 115	315	575	+ 260	820	740	− 80	16	14½	− 1½
VIII	......	......	......	......	......	......	0	225	+ 225	250	525	+ 275	825	740	− 85	18	15	− 3
IX	......	......	......	......	......	......	0	285	+ 285	220	500	+ 280	760	725	− 35	18	15¾	− 2¼
X	......	......	......	......	......	......	0	320	+ 320	185	500	+ 315	730	765	+ 35	18	16	− 2
XI	......	......	......	......	......	......	0	325	+ 325	150	500	+ 350	700	785	+ 85	18	15	− 3
XII	......	......	......	......	......	......	15	225	+ 210	190	515	+ 325	625	810	+ 185	17	14	− 3
XIII	......	......	......	......	......	......	50	125	+ 75	185	600	+ 415	590	835	+ 245	16	14	− 2
XIV	......	......	......	......	......	......	60	110	+ 50	175	625	+ 450	575	875	+ 300	17¼	14¼	− 3
XV	......	......	......	......	0	± 0	70	225	+ 155	275	800	+ 525	575	950	+ 375	16	12	− 4
XVI	......	......	......	......	350	+ 350	110	820	+ 710	320	1,050	+ 730	585	1,220	+ 635	16	9½	− 6½
XVII	......	......	......	40	1,075	+1,035	215	1,145	+ 930	450	1,275	+ 825	590	1,375	+ 785	10	9¾	− ¼
XVIII	......	......	......	130	800	+ 670	265	975	+ 710	490	1,190	+ 700	640	1,300	+ 660	6½	7¼	+ ¾
XIX	40	......	− 40	235	440	+ 205	330	675	+ 345	550	985	+ 435	660	1,180	+ 520	5	6¼	+ 1¼
XX	160	120	− 40	310	260	− 50	465	400	− 65	575	875	+ 300	690	1,185	+ 495	4	3	− 1
XXI	135	210	+ 75	325	285	− 40	445	500	+ 55	625	850	+ 225	725	1,150	+ 425	5	3	− 2
XXII	65	110	+ 45	355	325	− 30	475	440	− 35	620	890	+ 270	775	1,160	+ 385	5½	5½	± 0
XXIII	80	135	+ 55	375	350	− 25	530	525	− 5	650	965	+ 315	860	1,270	+ 410	5	3¾	− 1¼
XXIV	230	230	± 0	400	380	− 20	475	900	+ 425	735	1,285	+ 550	950	1,400	+ 450	5½	4½	− 1
XXV	330	360	+ 30	420	365	− 55	480	575	+ 95	750	1,175	+ 425	985	1,400	+ 415	5½	3½	− 2
XXVI	375	345	− 30	465	410	− 55	575	430	− 145	825	1,200	+ 375	1,075	1,425	+ 350	0	0	± 0
XXVII	370	370	± 0	635	575	− 60	840	1,120	+ 280	1,180	1,375	+ 195	1,350	1,500	+ 150	3	3	± 0
XXVIII	340	365	+ 25	820	675	− 145	1,115	1,160	+ 45	1,210	1,515	+ 305	1,430	1,635	+ 205	3	3¾	+ ¾
XXIX	375	400	+ 25	900	725	− 175	1,200	1,270	+ 70	1,450	1,580	+ 130	1,570	1,770	+ 200	5	4¾	− ¼
XXX	415	460	+ 45	915	765	− 150	1,175	1,290	+ 115	1,375	1,650	+ 275	1,625	1,870	+ 245	5	5	± 0
XXXI	450	450	± 0	840	780	− 60	1,020	1,260	+ 240	1,150	1,700	+ 550	1,720	1,910	+ 190	5	4½	− ½
XXXII	500	430	− 70	750	710	− 40	875	1,270	+ 395	1,525	1,710	+ 185	1,920	2,025	+ 105	4½	4½	± 0
XXXIII	550	487	− 63	710	645	− 65	835	1,285	+ 450	1,475	1,725	+ 250	2,100	2,080	− 20	4½	4½	± 0
XXXIV	470	525	+ 55	665	800	+ 135	790	1,280	+ 490	1,700	1,650	− 50	2,175	2,115	− 60	0	0	± 0
XXXV	265	550	+ 285	640	875	+ 235	1,360	1,250	− 110	1,635	1,590	− 45	2,240	2,125	− 115	3	3	± 0
XXXVI	75	565	+ 490	540	880	+ 340	1,175	1,240	+ 65	1,610	1,630	+ 20	2,230	2,165	− 65	4	4½	+ ½
XXXVII	......	540	+ 540	425	850	+ 425	1,050	1,100	+ 50	1,550	1,470	− 80	2,140	2,075	− 65	6	4½	1½
XXXVIII	......	......	......	360	290	− 70	950	920	− 30	1,610	1,415	− 195	1,910	1,920	+ 10	7	10	+ 3
Mean	......	......	+ 64	......	......	+ 100	......	......	+ 211	......	......	+ 303	......	......	+ 201	......	......	......

NOTE.—The normals, which are 500 feet apart, are drawn towards the channel from two datum-lines, the first running from Robbin's Reef light-house to Bedloe's Island flag-staff; the second, from Bedloe's Island flag-staff, through Ellis's Island flag-staff, to the New Jersey Central Railroad wharf.

ED. H. FOOTE, *Computer.*

TABLE NO. 2.—*Changes on the point of Jersey Flats, as shown by the surveys of* 1855 *and* 1871–'72.

Number of radius.	Distances from Robbin's Reef light of the 6, 12, 18, 24, and 30 feet curves.														
	6-feet curve.			12-feet curve.			18-feet curve.			24-feet curve.			30-feet curve.		
	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Advance + or retreat −	1855.	1871–'72.	Advance + or retreat −
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0.....	150	210	+ 60	495	630	+ 135	825	905	+ 80	930	1,065	+ 135	1,160	1,165	+ 5
I.....	240	200	− 40	635	750	+ 115	1,110	970	− 140	1,200	1,150	− 50	1,330	1,280	− 50
II....	325	165	− 160	925	925	± 0	1,395	1,180	− 215	1,540	1,490	− 50	1,875	1,675	− 200
III ..	375	175	− 200	1,030	995	− 35	1,615	1,555	− 60	2,030	1,970	− 60	2,500	2,250	− 250
IV...	400	190	− 210	1,040	970	− 70	1,640	1,470	− 170	1,980	2,050	+ 70	2,800	2,730	− 70
Mean	....	....	− 118	....	....	+ 28	....	....	− 115	....	....	− 14	....	....	− 133

NOTE.—The radii are drawn 22° 30′ apart, from Robbin's Reef light as a center, number 0 being perpendicular to a line from the light-house to the flag-staff on Bedloe's Island.

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TABLE NO. 3.—*Changes on the Jersey Flats, as shown by surveys of* 1855 *and* 1871–'72.

Between normals.	Increase or decrease of horizontal area.				
	6-feet plane.	12-feet plane.	18-feet plane.	24-feet plane.	30-feet plane.
	Square feet.	*Square feet.*	*Square feet.*	*Square feet.*	*Square feet.*
0 and II	....	+ 186, 250	+ 252, 500	+ 267, 500	− 7, 500
II and IV	....	+ 87, 500	+ 236, 250	+ 296, 250	+ 78, 500
IV and VI	....	....	+ 68, 750	+ 171, 250	+ 87, 500
VI and VIII	....	....	+ 131, 250	+ 242, 500	− 61, 250
VIII and X	....	....	+ 278, 750	+ 287, 500	− 30, 000
X and XII	....	....	+ 295, 000	+ 335, 000	+ 97, 500
XII and XIV	....	....	+ 102, 500	+ 401, 250	+ 243, 750
XIV and XVI	....	....	+ 267, 500	+ 557, 500	+ 421, 250
XVI and XVIII	....	+ 772, 500	+ 820, 000	+ 770, 000	+ 716, 250
XVIII and XX	....	+ 162, 500	+ 333, 750	+ 467, 500	+ 548, 750
XX and XXII	+ 38, 750	− 40, 000	+ 2, 500	+ 255, 000	+ 432, 500
XXII and XXIV	+ 38, 750	− 25, 000	+ 95, 000	+ 362, 500	+ 413, 750
XXIV and XXVI	+ 7, 500	− 46, 250	+ 117, 500	+ 443, 750	+ 407, 500
XXVI and XXVIII	− 1, 250	− 80, 000	+ 165, 000	+ 267, 500	+ 213, 750
XXVIII and XXX	+ 30, 000	− 161, 250	+ 75, 000	+ 142, 500	+ 212, 500
XXX and XXXII	− 6, 250	− 77, 500	+ 247, 500	+ 322, 500	+ 187, 500
XXXII and XXXIV	− 35, 250	− 8, 750	+ 446, 250	+ 158, 750	+ 1, 250
XXXIV and XXXVI	+278, 750	+ 236, 750	+ 83, 750	− 30, 000	− 88, 750
XXXVI and XXXVII	....	+ 280, 000	+ 33, 750	− 83, 750	− 46, 250
Total	+351, 000	+1, 286, 750	+4, 052, 500	+5, 635, 000	+3, 828, 500

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TABLE No. 4.—*Changes on the Jersey Flats, New York Harbor, as shown by surveys of* 1855 *and* 1871–'72.

Between normals—	Increase or decrease of volume between depths of—					Total.
	Datum-line and 6 feet.	6 and 12 feet.	12 and 18 feet.	18 and 24 feet.	24 and 30 feet.	
	Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
0 and II		*+ 525,000	+ 1,316,250	+ 1,556,500	+ 765,000	+ 4,162,750
II and IV		*+ 82,000	+ 971,250	+ 1,597,500	+ 1,125,000	+ 3,775,750
IV and VI			+ 270,000	+ 720,000	+ 776,250	+ 1,766,250
VI and VIII			+ 271,250	+ 1,121,250	+ 543,750	+ 1,936,250
VIII and X			+ 342,500	+ 1,698,750	+ 772,500	+ 2,813,750
X and XII			+ 434,000	+ 1,887,500	+ 1,297,500	+ 3,619,000
XII and XIV			+ 267,250	+ 1,511,250	+ 1,435,000	+ 3,213,500
XIV and XVI			+ 1,196,750	+ 2,475,000	+ 1,936,250	+ 5,608,000
XVI and XVIII		*+1,078,000	+ 4,836,250	+ 4,770,000	+ 3,458,750	+14,143,000
XVIII and XX		+ 542,000	+ 1,777,500	+ 2,403,750	+ 3,051,250	+ 7,774,500
XX and XXII	+132,000	− 3,500	− 112,500	+ 772,500	+ 2,062,500	+ 2,851,000
XXII and XXIV	+ 96,000	+ 41,250	+ 460,000	+ 1,372,500	+ 2,328,750	+ 4,298,500
XXIV and XXVI	+190,000	− 116,250	+ 463,750	+ 1,683,750	+ 2,553,750	+ 4,775,000
XXVI and XXVIII	− 48,000	− 251,250	+ 105,000	+ 1,147,500	+ 1,443,750	+ 2,397,000
XXVIII and XXX	+ 40,000	− 393,750	− 258,750	+ 885,000	+ 1,267,500	+ 1,540,000
XXX and XXXII	+ 48,000	− 251,250	+ 510,000	+ 1,912,500	+ 1,717,500	+ 3,936,750
XXXII and XXXIV	+ 3,000	− 132,000	+ 1,312,500	+ 1,815,000	+ 480,000	+ 3,478,500
XXXIV and XXXVI	+341,000	+1,545,000	+ 960,000	+ 161,250	− 356,250	+ 2,651,000
XXXVI and XXXVIII		+1,917,500	+ 941,250	− 150,000	− 390,000	+ 2,318,750
Total	+802,000	+4,582,750	+16,064,250	+29,141,500	+26,268,750	+76,859,250

NOTE.—Those volumes marked with an asterisk (*) are between the datum line and the 12-feet line.

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TABLE NO. 5.—*Changes in the bottom of New York Harbor, in the vicinity of the Middle Ground Shoal, from a comparison of the surveys of 1855 and 1872.*

DEPTHS IN FEET ON THE NORMALS, AT POINTS 250 FEET APART, EACH WAY, FROM THE AXIS, IN 1855.

No. of normal from Bay Ridge flag-staff.	Distances from the axis toward the main channel.																						Axis.
	5500	5250	5000	4750	4500	4250	4000	3750	3500	3250	3000	2750	2500	2250	2000	1750	1500	1250	1000	750	500	250	
0	....	....	31	29½	29	26	24	23	23½	22	20	20	21	22½	29	35	40	45	41	44	28	6	0
I	....	....	30	28	26½	25	24	23	22	21	20	19	18½	22	25½	28	35	41	42	38	28	9	0
II	....	33	29	27½	26	25	24	23	22	20½	20	19	18½	22	26	28	35	41	42	42½	28	12	10
III	....	30	28	27	25	22	23	21½	21	20	20	17½	18	20	22	26	30	40	39	40	37	20	18
IV	....	30	28	27	26	25	22½	20½	25	21	18	17½	16	17	18	20	21	23	30	38	35	28	19
V	31	29	27	26	26	25	22	21½	21	19	18	17	16½	16	16	17	22	26	29	34	33	30	23
VI	30½	30	29	28	26	24	23½	23	22	21	18	17	16	15	14½	19	20	20	23	30	32	33	27
VII	31½	28½	28	26½	26	24	23	22	23	20	18	16	15	14	18½	18½	19½	20	23	26	30	31	30
VIII	31	29	28½	29	26	26	23	23	21	20	17½	16	15	15	15½	16	17½	18½	18½	21	24	30	31
IX	32	29	28	27½	26	25	23	22½	22	22	17½	16½	15½	15	15	16	16	17	20	20	20	21	30
X	31	29½	28	27½	26	25	25	23	20	19	18	16½	16	15	14½	14½	14	13½	19	16½	17½	17½	24
XI	....	30	29	28	26	25	25	24	22½	21	20	16½	16	15	15	15½	14½	14	14	18	18	20	25
XII	....	30	29½	28	25	22	22½	23	21½	20	20	17½	16	16	15	14	14	14	14	13½	15	15	19
XIII	....	31	29	27	26	25	24	23	22	21½	21	18	16½	16	15	14½	14	14	13½	14	15	13	17
XIV	....	....	30	29	28	27	25	23	22	22	21½	19	17½	17½	16	14	13	14	14	14	13½	13	16
XV	....	....	33	29½	27	28	27	24	22	22	21	19½	17½	17	17	16	15	14½	14	13½	14	13½	15
XVI	....	....	....	30	28½	27	24	24½	23	22	21½	21	18	17½	17	16½	16½	15½	15	15	14	14	13½
XVII	....	....	....	31½	29	29	26½	26	23	22	21	22	18½	18	17	16	15	15	16	14½	13½	13½	12½
XVIII	....	....	....	....	31	27	26	25	23	23	21	22	20	18½	17½	18	16½	15½	16	15	14½	13½	12
XIX	....	....	....	....	31	29	27½	25	23	22	22	22	20½	19½	18½	17½	17	17½	16½	16½	16	13½	11
XX	....	....	....	....	....	30	29	28	24	24	23	22	21	20	19½	18	17	19½	19	17	15½	12½	10½
XXI	....	....	....	....	....	30	30	28	25	22	22	22½	23	19	19	18½	17½	19	18	16	15	13½	11
XXII	....	....	....	....	....	....	30	29	27	25	24	24	24	24	22½	20½	20½	20	19	18	15	12	10½
XXIII	....	....	....	....	....	....	31	29	28	27	25	25	25	24½	24½	21	21	22	18½	18	14	11	10½
XXIV	....	....	....	....	....	....	....	30	29	27½	26	27	28	26½	23	24	21	20	20	17½	14½	12	10
XXV	....	....	....	....	....	....	....	31	30	29	28½	28	29	29	28	29	27½	22	18	16	14	12½	12
XXVI	....	....	....	....	....	....	....	....	30	30	30	31	31½	32	31	29	27	24	20	16	15	15	11½
XXVII	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	33	28	24	19	17½	16½	18	20
XXVIII	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	33	28	23	18	18	25	27
XXIX	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	31	29	26	24	29	25
XXX	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	30	27½	23	19	21
XXXI	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	32	26	24	19	15

No. of normal from Bay Ridge flag-staff.	Distances from the axis toward the shore.																					
	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500
0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
I	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
II	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
III	12	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
IV	16	9	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
V	18	16½	11	4½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
VI	21	16½	14½	9	4½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
VII	25	18	16	13½	7	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
VIII	30	25	17	14	12	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
IX	27	24	18	16	14	11½	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
X	28	26	24	18	15	13	10	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....
XI	23½	28	22	20	17	14	11½	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....
XII	21	24	24	24	20	16	14	11	5	....	....	....	....	....	....	....	....	....	....	....	....	....
XIII	19	21	24	27	22	18	15	13	11	6	....	....	....	....	....	....	....	....	....	....	....	....
XIV	17	18	20	22½	24	23	17	14	12½	9	6	....	....	....	....	....	....	....	....	....	....	....
XV	17	16½	18	19	20	19	18	16	14	12	9	6	....	....	....	....	....	....	....	....	....	....
XVI	15	17	17	17	19	19	18	16	13	12	10½	10	6	....	....	....	....	....	....	....	....	....
XVII	11½	15	16	16	17½	18½	18½	16	14	12	10½	9	7½	4	....	....	....	....	....	....	....	....
XVIII	10½	13	14	15	16	16½	17½	15	14	11	9	8	8	8	7	6	....	....	....	....	....	....
XIX	10½	11	14	15	15½	16	16	14	13	10½	9	6½	7	7	7	7	7	6	....	....	....	....
XX	10½	10	12	13½	14½	15	14	13	12½	9	7½	6	6	6	6	6½	7½	7½	7	6	....	....
XXI	10½	10½	12	14	14	15	14½	13½	12	11	9	6	5	5	6	7	6½	6½	7	6½	5	....
XXII	11	10	12	14	15	14½	14	13	11½	10	7	6	6	6	6	7	7	7	7½	7	6	....
XXIII	11	10½	12½	15	15	14	12½	11	10	7½	6	6	6	5	6	7	7	7	7	7	6	....
XXIV	11	10½	13½	16	16	14	12	10	9	8½	8	7	7	6½	6½	7	7	7	6½	6½	6	....
XXV	11	12½	16½	18	16	13½	11	9	8½	9	8	7	6	6	6	5½	....	....	....	....	....	....
XXVI	14	16	22	19	15	12	10½	9½	10	9½	6	....	....	....	....	....	....	....	....	....	....	....
XXVII	24	28	22	16	13	11½	0	9	6	....	....	....	....	....	....	....	....	....	....	....	....	....
XXVIII	23	18½	10	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
XXIX	20	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
XXX	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
XXXI	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

ED. H. FOOTE, *Computer.*

TABLE No. 6.—*Changes in the bottom of New York Harbor, in the vicinity of the Middle Ground Shoal, from a comparison of the surveys of* 1855 *and* 1872.

DEPTHS IN FEET ON THE NORMALS, AT DISTANCES OF 250 FEET, EACH WAY, FROM THE AXIS, IN 1872.

Distances from the axis toward the main channel.

No. of normal from Bay Ridge flag-staff.	5500	5250	5000	4750	4500	4250	4000	3750	3500	3250	3000	2750	2500	2250	2000	1750	1500	1250	1000	750	500	250
0			28	27	26	25½	24½	24	23	24	22	20	20	23	27	31	36	42½	41	38	26	17
I			27	27	24	22	21	21	20	20	19	18	21	23	26	30	36	45	43½	42	28	12
II		28	28	27	24	21½	21	20	19½	19	18	18	18	21	24	27	31	36	44	38	33½	18
III		24	28	27	25	22	22	24	21½	19	18	16	16	17	20	21	22½	38½	38½	37	34	24
IV		30	30	27	24	25	24	23	19	19	18	17½	16	15½	16	18½	20	30	34	35	33	28
V	30	30	29	28	26	25	23	21	20	19	18	17½	17½	17½	18	19	19	22	26	34	32½	30
VI	31	30	26	26½	24	23½	23	22	20½	19	19	16	15½	15½	15½	15½	17	20	26	32	32	30
VII	32	30	29	27	25	24	22½	22	21	19	19	17	17	15½	14	14	17	17½	20	24	29	32
VIII	31½	30	29	25	24½	23	22½	21½	21	20	18	17	16	15	14	14	13½	16	18½	20	28	29
IX	31	29½	29	26½	25½	24	23	21	20½	20	18	18	16½	15	14	14	14	14	18	18	22	24
X	30	29	28	26½	25	24	23	22½	21	21	19	18	17	14	14	13	13	13½	16	20	19½	20
XI		30	28	26½	25	23	23	20	21	19	19	18	17	15½	15	14	13½	14	13½	15	17	19
XII		30½	29	26	26	24	23	22	21	19	18	16½	17½	16	15½	14½	14	14	14	14	13½	17
XIII		30	29	28	26	26	24	22	20½	19½	18½	17½	17	17	15½	15	15	13½	14	13	13½	15
XIV			30	28½	28	25	24	22	21	20	18½	18½	18	17	16½	16	14	15	14	13½	14	14½
XV				31	27	26	25	23	22	20½	19½	18	18	17	17½	17	16	15	13½	13½	13½	14½
XVI				30	28	26	25	23½	20½	20	19½	18½	18½	19	17½	16	16	14½	14½	14½	14½	15
XVII				29	27	26	25	23	21	20	20	18½	20	18	16½	17	15½	14½	14½	14½	15	14
XVIII					30	28	26½	24½	22	21	20	20	21	20	18	17½	16	16	16½	17	16	14
XIX					31	29	26	24½	24	22	21	20½	21	20	19	18½	17	17½	16½	17	16	15½
XX						30	28	26	24	21	21	21	21	20	20	18	17	17½	18	16	15½	13
XXI						32	29½	27½	26	23	21	21	23	21½	20	19	19½	19	18	16	15½	14
XXII							30	28	27	24	25	24	23	22½	22	20	18½	19	20	17	15	13
XXIII							31	28½	28	28	25	24	24	24	24	23	21½	21	21	18	15	12½
XXIV								30	29	29	28	25	25	26	26	24	25	20	18	16	14	12
XXV								30	29	29	30	30	26	27	29	28	26	22	18	17	15	11½
XXVI															31	29½	26½	24	20	16	15	13
XXVII																30	29	24	21½	19½	16½	19
XXVIII																	31	29½	26	23	20	23
XXIX																		32	28	26	25	26
XXX																		40	29½	28	26½	25
XXXI																			30	27	24	17½

Axis and distances from the axis toward shore.

No. of normal from Bay Ridge flag-staff.	Axis.	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500
0	0																						
I	0																						
II	9																						
III	18	13	7½	4																			
IV	23	17	12	6																			
V	26	21	15	9	4																		
VI	28	25	19	14	8	4																	
VII	29	27	22	16	13	10	4																
VIII	29	27	24	17	15	12	6																
IX	29	28	26	21	17	15	12	3½															
X	26½	28	24	18	17	15	12	10	4														
XI	23	28	26	20½	18	16	14	11	8	3													
XII	19	20	25	24	22	19	14	14	10	6													
XIII	17	19½	21	22½	25	19	16	13	12	9½	6												
XIV	13	13	19	21	23	22	21	18	16	13½	12	10½	5										
XV	16	17	16	18	19	19	17	15	14	12	12	10	5										
XVI	13	14	16½	15½	16	18	16½	15½	12	11	11	9	9	3									
XVII	12	12	16½	14½	16	16	16½	17	12	11	8	8	8½	9	7	4							
XVIII	12	11	14½	13	14½	15	15½	14	12	11	9½	8	8	7	6½	9	6						
XIX	13	11½	10½	12½	13½	14	14	13½	13	10	7	7	7	6	6	7	7	7	6				
XX	12½	11	11	12	13	14	14	13½	14	10	8	6	5	5½	7	7	7	7	7½	6½	5		
XXI	11½	11	10	11½	13	14	14	14	11	12	9	8	7	6	6	7	6	7½	7	7½	6½	6½	
XXII	11½	11	11½	12	13½	14	15	15	6	7	6	6	4	10	10	7	6	6	7	6	7	6	
XXIII	12	11	12	12	14	15	16	4	6½	6	5	5½	5	5	6	6	7	8	10	6	6½	7	
XXIV	12	12	12	13½	16	18	5	5	6	5	5½	5½	6	7	6½	7½	8	7	7½	10	10	7½	
XXV	11	11	15	19	18	2	6	7½	8	8½	7½	7	7	6									
XXVI	13	15	22	22½	23½	21	18	17½	16														
XXVII	20	29½	28																				
XXVIII	27½	25																					
XXIX	29																						
XXX	22																						
XXXI	10																						

ED. H. FOOTE, *Computer.*

TABLE NO. 7.—*Changes in the bottom of New York Harbor, in the vicinity of the Middle Ground Shoal, from a comparison of the surveys of 1855 and 1872.*

No. of normal from Bay Ridge flag-staff.	INCREASE (+) OR DECREASE (−) OF DEPTHS IN FEET ON NORMALS, AT POINTS 250 FEET APART, EACH WAY FROM THE AXIS. Distances from the axis toward the main channel.																					Axis or chord.
	5500	5250	5000	4750	4500	4250	4000	3750	3500	3250	3000	2750	2500	2250	2000	1750	1500	1250	1000	750	500	250	
0	....	....	− 3	− 2½	− 3	− ½	+ ½	+ 1	− ½	+ 2	+ 2	0	− 1	+ ½	− 2	− 4	− 4	− 2½	0	− 6	− 2	+11	0
I	....	....	− 3	− 1	− 2½	− 3	− 3	− 2	− 2	− 1	− 1	− 1	+ 2½	+ 1	+ ½	+ 2	+ 1	+ 4	+ 1½	+ 4	0	+ 3	0
II	....	− 5	− 1	− ½	− 2	− 3½	− 3	− 3	− 2½	− 1½	− 2	− 1	− ½	− 1	− 2	− 1	− 4	− 5	+ 2	− 4½	+ 5½	+ 6	− 1
III	....	− 6	0	0	0	0	− 1	+ 2½	+ ½	− 1	− 2	− 1½	− 2	− 3	− 2	− 5	− 7½	− 1½	− ½	− 3	− 3	+ 4	0
IV	....	0	+ 2	0	− 2	0	+ 1½	+ 2½	− 6	− 2	0	0	0	− 1½	− 2	− 1½	− 1	+ 7	+ 4	− 3	− 2	0	+ 4
V	− 1	+ 1	+ 2	+ 2	0	0	+ 1	− ½	− 1	0	0	+ ½	+ 1	+ 1½	+ 2	+ 2	− 3	− 4	− 3	0	− ½	0	+ 3
VI	+ ½	0	− 3	− 1½	− 2	− ½	− ½	− 1	− 1½	− 2	+ 1	− 1	− ½	+ ½	+ 1	− 3½	− 3	0	+ 3	+ 2	0	− 3	+ 1
VII	+ ½	+ 1½	+ 1	+ ½	− 1	0	− ½	0	− 2	− 1	+ 1	+ 1	+ 2	+ 1½	− 4½	− 4½	− 1½	− 2½	− 3	− 2	− 1	+ 1	− 1
VIII	+ ½	+ 1	+ ½	− 4	− 1½	− 3	− ½	− 1½	0	0	+ ½	+ 1	+ 1	0	− 1½	− 2	− 4	− 2½	0	− 1	+ 4	− 1	− 2
IX	− 1	+ ½	+ 1	− 1	− ½	− 1	0	− 1½	− 1½	− 2	+ ½	+ 1½	+ 1	0	− 1	− 2	− 2	− 3	− 2	− 2	+ 2	+ 3	− 1
X	− 1	− ½	0	− 1	− 1	− 1	− 2	− ½	+ 1	+ 2	+ 1	+ 1½	+ 1	− 1	− ½	− 1½	− 1	0	− 3	+ 3½	+ 2	+ 2½	− 1½
XI	....	0	− 1	− 1½	− 1	− 2	− 2	− 4	− 1½	− 2	− 1	+ 1½	+ 1	+ ½	0	− 1½	− 1	0	− ½	− 3	− 1	− 1	− 2
XII	....	+ ½	− ½	− 2	+ 1	+ 2	+ ½	− 1	− ½	− 1	− 2	− 1	+ 1½	0	+ ½	+ ½	0	0	0	+ ½	− 1½	+ 2	0
XIII	....	− 1	0	+ 1	0	+ 1	0	− 1	− 1½	− 2	− 2½	− ½	+ ½	+ 1	+ ½	+ ½	+ 1	− ½	+ ½	− 1	− 1½	+ 2	0
XIV	....	....	0	− ½	0	− 2	− 1	− 1	− 1	− 2	− 3	− ½	+ ½	− ½	+ ½	+ 2	+ 1	+ 1	0	− ½	+ ½	+ ½	− 3
XV	....	....	....	+ 1½	0	− 2	− 2	− 1	0	− 1½	− 1½	− 1½	+ ½	0	+ ½	+ 1	+ 1	+ ½	− ½	0	+ ½	+ 1	+ 1
XVI	....	....	....	0	− ½	− 1	+ 1	− 1	− 2½	− 2	− 2	− 2½	+ ½	+ 1½	+ ½	− ½	− ½	− 1	− ½	− ½	+ ½	+ 1	− ½
XVII	....	....	....	− 2½	− 2	− 3	− 1½	− 3	− 2	− 2	− 1	− 3½	1½	0	− ½	+ 1	+ ½	− ½	− 1½	0	+ 1½	+ ½	− ½
XVIII	....	....	....	....	− 1	+ 1	+ ½	− ½	− 1	− 2	− 1	− 2	+ 1	+ 1½	+ ½	− ½	− ½	+ ½	+ ½	+ 2	+ 1½	+ ½	0
XIX	....	....	....	....	0	0	− 1½	− ½	+ 1	0	− 1	− 1½	+ ½	+ ½	+ ½	+ 1	0	0	+ ½	+ ½	0	+ 2	+ 2
XX	....	....	....	....	....	0	− 1	− 2	0	− 3	− 2	− 1	0	0	+ ½	0	0	− 2	− 1	− 1	0	+ ½	+ 2
XXI	....	....	....	....	....	+ 2	− ½	− ½	+ 1	+ 1	− 1	− 1½	0	+ 2½	+ 1	+ ½	+ 2	0	0	0	+ ½	+ ½	+ 1½
XXII	....	....	....	....	....	....	0	− 1	0	− 1	+ 1	0	− 1	− 1½	− ½	− ½	− 2	− 1	+ 1	− 1	0	+ 1	+ 1
XXIII	....	....	....	....	....	....	0	− ½	0	+ 1	0	− 1	− 1	− ½	− ½	+ 2	+ ½	− 1	+ 2½	0	+ 1	+ 1½	+ 1½
XXIV	....	....	....	....	....	....	....	0	0	+ 1½	+ 2	− 2	− 3	− ½	+ 3	0	+ 4	0	− 2	− 1½	− ½	0	+ 2
XXV	....	....	....	....	....	....	....	− 1	− 1	0	+ 1½	+ 2	− 3	− 2	+ 1	− 1	− 1½	0	0	+ 1	+ 1	− 1	− 1
XXVI	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	+ ½	− ½	0	0	0	0	− 2	+ 1½
XXVII	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	− 3	+ 1	0	+ 2½	+ 2	0	+ 1	0
XXVIII	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	− 2	+ 1½	+ 3	+ 5	+ 2	− 2	+ ½
XXIX	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+ 1	− 1	0	+ 1	− 3	+ 4
XXX	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	− ½	+ ½	+ 3½	+ 6	+ 1
XXXI	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	− 2	+ 1	0	− 1½	− 5
Means	−0.10	−0.45	−0.25	−0.62	−0.92	−0.77	−0.68	−0.88	−0.95	−0.84	−0.57	−0.58	+0.24	+0.07	−0.13	−0.57	−0.86	−0.37	+0.03	−0.18	+0.48	+1.01	+0.35

NOTE.—Mean depth, channelward, of axis = − 0.28.

TABLE NO. 7.—*Changes in the bottom of New York Harbor, &c.*—Continued.

No. of normal from Bay Ridge flag-staff.	INCREASE (+) OR DECREASE (−) OF DEPTHS IN FEET ON NORMALS, AT POINTS 250 FEET APART, EACH WAY FROM THE AXIS. Distances from the axis toward the shore.																					
	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	Means.
0																							− 0.63
I																							+ 0.08
II																							− 0.89
III	+ 1	+ 2½																					− 1.16
IV	+ 1	+ 3	+ 1																				+ 0.17
V	+ 3	− 1½	− 2	− ½																			+ 0.11
VI	+ 4	+ 2½	− ½	− 1	− ½																		− 0.35
VII	+ 2	+ 4	0	− ½	+ 3	0																	− 0.22
VIII	− 3	− 1	0	+ 1	0	0																	− 0.69
IX	+ 1	+ 2	+ 3	+ 1	+ 1	+ ½	− 1½																− 0.13
X	0	− 2	− 6	− 1	0	− 1	0	0															− 0.35
XI	+ 4½	− 2	− 1½	− 2	− 1	0	− ½	+ 2															− 0.84
XII	− 1	+ 1	0	− 2	− 1	− 2	0	− 1	+ 1														− 0.21
XIII	+ ½	0	− 1½	− 2	− 3	− 2	− 2	− 1	− 1½	0													− 0.50
XIV	− 4	+ 1	+ 1	+ ½	− 2	− 2	+ 1	+ 2	+ 1	+ 3	+ 4½												− 0.14
XV	0	− ½	0	0	− 1	− 2	− 3	− 2	− 2	0	+ 1	− 1											− 0.41
XVI	− 1	− ½	− 1½	− 1	− 1	− 2½	− 2½	− 4	− 2	− 1	− 1½	− 1	− 3										− 0.97
XVII	+ ½	+ 1½	− 1½	0	− 1½	− 2	− 1½	− 4	− 3	− 4	− 2½	− ½	+ 1½	+ 3									− 0.99
XVIII	+ ½	+ 1½	− 1	− ½	− 1	− 1	− 3½	− 3	− 3	− 1½	− 1	0	− 1	− 1½	+ 2	0							− 0.35
XIX	+ 1	− ½	− 1½	− 1½	− 1½	− 2	− 2½	− 1	− 3	− 3½	− 2	+ ½	− 1	− 1	0	0	0	0					− 0.40
XX	+ ½	+ 1	0	− ½	− ½	− 1	− ½	+ 1	− 2½	− 1	− 1½	− 1	− ½	+ 1	+ 1	+ ½	− ½	0	− ½	− 1			− 0.42
XXI	+ ½	− ½	− ½	− 1	0	− 1	− ½	− 2½	0	− 2	− 1	+ 1	+ 1	+ 1	+ 1	− 1	+ 1	+ ½	+ ½	0	+ 1½		+ 0.14
XXII	0	+ 1½	0	− ½	− 1	+ ½	+ 1	− 7	− 4½	− 4	− 1	− 2	+ 4	+ 4	+ 1	− 1	− 1	0	− 1½	0	0		− 0.49
XXIII	0	+ 1½	− ½	− 1	0	+ 2	− 8½	− 4½	− 4	− 2½	− ½	− 1	− 1	+ 1	0	0	+ 1	+ 3	− 1	− ½	+ 1		− 0.30
XXIV	+ 1	+ 1½	0	0	+ 2	− 9	− 7	− 4	− 4	− 3	− 2½	− 1	0	0	+ 1	+ 1	0	+ ½	+ 3½	+ 3½	+ 1½		− 0.35
XXV	0	+ 2½	+ 2½	0	−14	− 7½	− 3½	− 1	0	− 1½	− 1	0	0										− 0.98
XXVI	+ 1	+ 6	+ ½	+ 4½	+ 6	+ 6	+ 7	+ 6½															+ 2.11
XXVII	+ 5½	0																					+ 1.17
XXVIII	+ 2																						+ 1.43
XXIX																							− 0.10
XXX																							+ 2.62
XXXI																							− 1.00
Means	+0.76	+0.97	−0.49	−0.57	−0.99	−1.53	−1.81	−1.67	−2.15	−1.69	−0.98	−0.45	+0.17	+0.86	+0.75	−0.17	+0.10	+0.75	−0.12	+0.19	+0.83		

NOTE.—**Mean depth, shoreward, of axis = — 0.47; mean depth in Gowanus Bay, exclusive of Erie Basin = — 0.43; mean depth in Erie Basin = — 0.61.**

ED. H. FOOTE, *Computer.*

TABLE No. 8.—*Currents of Gedney's Channel*, 1858.

Time.	Velocity.	Time.	Velocity.	Time.	Velocity.	Time.	Velocity.
h. m.	*Naut. miles.*	*h. m.*	*Naut. miles.*	*h. m.*	*Naut. miles.*	*h. m.*	*Naut. miles.*
Aug. 7 13 00	−0.05	Aug. 7 19 30	−0.10	Aug. 8 2 00	+0.15	Aug. 8 8 30	−0.65
13 30	+0.40	20 00	−0.75	2 30	+0.40	9 00	−1.20
14 00	+1.00	20 30	−1.00	3 00	+0.75	9 30	−1.65
14 30	+1.20	21 00	−1.45	3 30	+1.00	10 00	−1.98
15 00	+1.35	21 30	−1.85	4 00	+1.15	10 30	−2.00
15 30	+1.45	22 00	−2.15	4 30	+1.25	11 00	−1.87
16 00	+1.52	22 30	−1.80	5 00	+1.25	11 30	−1.70
16 30	+1.42	23 00	−1.65	5 30	+1.20	12 00	−1.47
17 00	+1.32	23 30	−1.48	6 00	+0.90	12 30	−1.22
17 30	+1.20	Aug. 8 0 00	−1.40	6 30	+0.70	13 00	−1.00
18 00	+1.07	0 30	−1.05	7 00	+0.35	13 30	−0.45
18 30	+0.80	1 00	−0.80	7 30	+0.07	14 00	−0.20
19 00	+0.57	1 30	−0.40	8 00	−0.20		

NOTE.—A diagram accompanies this table. Between the hours of 10 and 13, on the 8th, some irregularities of the observed curve are swept out by a graphical correction.

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TABLE No. 9.—*Tides and currents observed in the Hudson River and seaward approaches.*

Localities.	FLOOD-CURRENT. Middle time after transit.	Direction.	Maximum velocity in nautical miles.	Number of determinations.	EBB-CURRENT. Middle time after transit.	Direction.	Maximum velocity in nautical miles.	Number of determinations.	TIDES. Intervals. H. W.	Intervals. L. W.	Rise and fall in feet.	Distance from Sandy Hook in nautical miles.
	h. m.				*h. m.*				*h. m.*	*h. m.*		
Forty miles south of Fire Island Light*	1 41	S. W.	0.70	1	8 16	E.	0.33	1				−60
Sandy Hook light-ship*	5 18	N. W.	0.57	4	12 38	S.E.	0.45	2				−6 3-4
Station J. Gedney's Channel	5 30	W.	1.45	2	11 38	E.	2.07	2				−3
Sandy Hook									VII XXIX	XIII XLIV	4.8	0
Main channel, between east and west banks	7 03	N.	1.40	25	13 3	S.	2.10	23				5 1-4
Narrows	6 57	N. W.	1.10	8	13 10	S.E.	1.60	7				7 1-2
Main channel, between Governor's and Bedloe's Isl'ds.	7 54	N.	0.94		14 4	S.	1.70		VIII XIII	XIV XXXVIII	4.4	13 1-6
Off Forty-second street, Hudson River	8 55	N.	1.47		14 55	S.	2.78					18 1-8
Off Ninety-sixth street, Hudson River	8 37	N.	1.17	1	15 1	S.	1.85	2				20 5-8
Off Dobb's Ferry	9 32	N.	1.35	1	16 23	S.	1.25	1	IX VIII	XVI XXXVII	3.6	34 1-4
Off Tarrytown	10 12	N.	1.00	1	15 51	S.	0.75	1			3.5	38 1-4
Off Teller's Point					17 2	S.	0.70	2				43 1-2
Off Verplank's Point					16 50	S.	0.70	2	X LIII	XVIII V	3.1	49 1-2
Off Iona Island					17 3	S.	1.10	1				53 1-4
Off Denning's Landing	10 37	N.	0.60	1	17 3	S.	1.60	2				56 3-4
West Point									XI L	XIX VI		59 1-2
Off Cold Spring	10 39	N.	0.92	1	17 13	S.	1.40	1			2.7	61
Off New Windsor	10 48	N.	1.10	3		S.	1.40	1				65
Off Carthage	11 5	N.	1.30	2		S.	1.20	2				70 1-4
Off Barnegat	11 11	N.	1.20	2		S.	1.40	1				75
Off Poughkeepsie	11 6	N.	0.90	1		S.			XIII XXXIX	XX LIV	3.2	79 1-4

* Feeble and irregular.

TABLE No. 10.—*Tidal elements of Hudson River adjusted.*

Distance from Sandy Hook in nautical miles.	FLOOD.		EBB.		TIDES.			Mean depth of channel.	Square root of half-depth.	Mean depth at half-tide for entire width.	Mean width.	Mean section.	Mean perimeter.	Mean radius.	Changes of course.		General locality.
	Middle time after transit.	Direction.	Middle time after transit.	Direction.	Intervals. High water.	Intervals. Low water.	Rise and fall.								Maximum.	Sum.	
	h. m.		h. m.		h. m.	h. m.	Ft.	Ft.	Ft.	Ft.	Ft.	Sq. ft.	Ft.	Ft.	°	°	
0	6 2	W'd.	12 18	E'd.	0 0	0 0	4.8										Sandy Hook.
10	7 33	N'd.	13 32	S'd.	0 XXV	0 XXIV	4.4	52	5.1								Quarantine, New York Bay.
20	8 42	N'd.	15 3	S'd.	0 LIX	I VIII	4.2	59	5.4								Eighty-sixth street.
30	9 27	N'd.	15 57	S'd.	I XXXIII	I XXXIX	3.9	52	5.1	23	4,870	112,000	4,925	22.74	10	10	Yonkers, Tappan Sea.
40	10 5	N'd.	16 35	S'd.	II IX	II XXVI	3.5	43	4.6	16	8,860	139,000	8,894	15.63	15	15	Sleepy Hollow, Haverstraw Bay.
50	10 33	N'd.	17 0	S'd.	II XL	III XXVII	3.1	42	4.6	16	10,970	177,000	11,133	15.90	50	89	Verplanck's Point.
60	10 50	N'd.	17 10	S'd.	III XXX	IV XXII	2.8	106	7.3	44	2,740	121,000	2,893	41.82	73	288	Highlands.
70	11 4	N'd.	......	......	IV XXVI	V VII	3.0	60	5.5	26	5,080	134,000	5,125	26.14	40	87	Carthage.
80	11 12	N'd.	......	......	V XXVI	V LVI	3.2	68	5.8	38	3,140	120,000	3,220	37.27	33	81	Poughkeepsie.

NOTE.—In plotting the courses we have drawn the longest possible lines within the channel bounded by the 18-feet curves; each line beginning and ending in the middle of the channel as thus bounded.

ED. H. FOOTE, *Computer.*

TABLE No. 11.—*Tides and currents observed in the East River and its approaches.*

Localities.	FLOOD-CURRENT.				EBB-CURRENT.				TIDES.			Distance from Sandy Hook in nautical miles.
	Middle time after transit.	Azimuth.	Maximum velocity in nautical miles.	Number of determinations.	Middle time after transit.	Azimuth.	Maximum velocity in nautical miles.	Number of determinations.	Intervals. L. W.	Intervals. H. W.	Rise and fall.	
	h. m.	°			h. m.	°			h. m.	h. m.	Ft.	
Main channel (off Sandy Hook)	5 0	70	2.03	3	11 15	274	2.17	2	VII XXIX	......	......	1.5
Narrows	6 57	148	1.10	8	13 10	330	1.60	7	......	......	......	7¼
Buttermilk Channel	6 33	North'd	1.43	......	12 38	South'd	1.77	......	VIII XIII	XIV XXIX	4.24	12
East of Wall street ferry	6 39	...do..	......	......	12 28	...do..	......	......	......	......	......	14¼
South end of Blackwell's Island channels	6 32	...do..	2.40	......	12 40	...do..	2.90	......	......	......	......	18¼
North end of Blackwell's Island channels	6 30	...do..	4.20	......	12 38	...do..	4.20	......	X VI	XVI XX	4.45	20
Hallet's Point	......	East'd	8.50	......	......	West'd	4.4	......	XI VII	......	......	20½
Pot Cove	......	...do	......	......	......	...do	......	......	XI XXIX	XVII LVIII	5.68	20¾
Polhemus Dock to Lawrence P't	7 06	...do..	3.10	......	13 12	...do..	2.30	......	......	......	......	22
Throg's Neck	†6 33	...do..	0.75	......	12 43	...do..	0.70	......	XI XX	......		26¾
	‡4 15	...do..	1.50	......	10 25	...do..	0.80	......			......	
Execution Rocks	4 8	...do..	0.60	......	10 18	...do..	0.50	......	......	......	......	32
Middle of Sound	*3 0	......	......	......	......	......	......	......	......	......	......	......
Race	2 1	East'd	......	......	9 6	West'd	......	......	IX XXXVIII	......	......	110¼

* Computed from Mr. Schott's table, page 170, of Annual Report of Coast Survey for 1854. † Neaps. ‡ Springs.

TABLE No. 12.—*Currents at different depths in the Hudson River and New York Harbor, from observations of* 1858 *and* 1859.

Lunar hours.	Station in Gedney's Channel, Aug. 7, 1858.						Station in main ship-channel, off Sandy Hook, Aug. 8, 9, 10, 1858.					
	Velocity at surface.	Direction.	Velocity at 11¼ feet.	Direction.	Velocity at 26½ feet.	Direction.	Velocity at surface.	Direction.	Velocity at 11¼ feet.	Direction.	Velocity at 40 feet.	Direction.
0	1.69	Eastward.	1.79	Eastward.	1.53	Eastward.	2.13	Eastward.	2.38	Eastward.	1.04	Eastward.
I	1.26	...do	1.32	...do	0.94	...do	1.17	...do	1.83	...do	0.75	Do.
II	0.30	...do	0.13	...do			0.80	...do	0.71	...do	0.13	Do.
III	0.78	Westward.	0.95	Westward.	0.61	Westward.	0.87	Westward.	0.97	Westward.	0.68	Westward.
IV	1.35	...do	1.57	...do	0.68	...do	1.56	...do	1.89	...do	0.59	Do.
V	1.50	...do	1.77	...do	0.83	...do	1.89	...do	2.19	...do	0.57	Do.
VI	1.32	...do	1.52	...do	0.73	...do	1.56	...do	1.73	...do	0.50	Do.
VII	1.03	...do	1.19	...do	0.68	...do	0.62	...do	0.84	...do	0.69	Do.
VIII	0.06	Eastward.	0.11				0.96	Eastward.	0.78	Eastward.		
IX	0.76	...do	0.75	Eastward.			1.62	...do	1.62	...do	0.67	Eastward.
X	1.78	...do	1.55	...do	0.40	Eastward.	1.92	...do	1.76	...do	0.84	Do.
XI	2.05	...do	1.93	...do	1.31	...do	2.15	...do	2.31	...do	0.97	Do.

Lunar hours.	Station between east and west banks, June 24, 25, 1859.						Station in Narrows, July 31 and Aug. 1, 1858.					
	Velocity at surface.	Direction.	Velocity at 11 feet.	Direction.	Velocity at 34 feet.	Direction.	Velocity at surface.	Direction.	Velocity at 24 feet.	Direction.	Velocity at 92 feet.	Direction.
0	1.08	Southward	1.07	Southward	0.02	Northward	1.56	Southward	1.45	Southward	0.20	Northward.
I	1.49	...do	1.17	...do	0.07	Southward	1.48	...do	1.76	...do	0.22	Do.
II	1.76	...do	1.09	...do	0.25	Northward	1.51	...do	1.24	...do	0.55	Do.
III	1.43	...do	0.86	...do	0.38	...do	1.02	...do	0.65	...do	0.99	Do.
IV	0.94	...do	0.50	...do	0.32	...do	0.15	...do	0.42	Northward	0.98	Do.
V	0.40	...do	0.01	Northward	0.20	...do	0.52	Northward	0.55	...do	0.85	Do.
VI	0.16	Northward	0.64	...do	0.49	...do	0.86	...do	0.73	...do	1.48	Do.
VII	0.75	...do	0.94	...do	0.44	...do	1.03	...do	1.08	...do	1.93	Do.
VIII	0.71	...do	0.68(?)	...do	0.06(?)	...do	0.57	...do	0.93	...do	1.58	Do.
IX	0.50	...do	0.61	...do	0.05	...do	0.20	Southward	0.30	...do	0.42	Do.
X	0.51	Southward	0.40	Southward	0.08	...do	0.81	...do	0.70	Southward	0.19	Southward.
XI	0.88	...do	0.89(?)	...do	0.01	Southward	1.23	...do	1.23	...do	0.06	Do.

Lunar hours.	Station off Robbin's Reef, July 7, 8, 1859.						Station between Governor's and Bedloe's Islands, Sept. 1, 2, 1858.					
	Velocity at surface.	Direction.	Velocity at 12 feet.	Direction.	Velocity at 48 feet.	Direction.	Velocity at surface.	Direction.	Velocity at 11¼ feet.	Direction.	Velocity at 68 feet.	Direction.
0	0.87	Southward	0.97	Southward	0.34	Southward	1.45	Southward	1.69	Southward	0.31	Southward.
I	1.24	...do	1.43	...do	0.40	...do	1.45	...do	1.64	...do	0.54	Do.
II	1.26	...do	1.52	...do	0.41	...do	1.45	...do	1.45	...do	0.53	Do.
III	0.86	...do	1.10	...do	0.29	...do	1.26	...do	1.01	...do	0.53	Northward.
IV	0.55	...do	0.55	...do	0.08	Northward	0.91	...do	0.48	...do	1.66	Do.
V	0.40	...do	0.32	...do	0.70	...do	0.38(?)	...do	0.09(?)	Northward	1.09(?)	Do.
VI	0.47	...do	0.41(?)	Northward	1.34	...do	0.31(?)	Northward	0.63(?)	...do	1.35(?)	Do.
VII	0.06	Northward	0.69	...do	1.12	...do	0.63	...do	0.84	...do	1.41	Do.
VIII	0.25	...do	1.03	...do	1.05	...do	0.48	...do	0.81	...do	1.35	Do.
IX	0.32	...do	0.71	...do	0.75	...do	0.12	...do	0.35	...do	1.48(?)	Do.
X	0.01	Southward	0.38	...do	0.15	...do	0.41	Southward	0.53	Southward	0.22(?)	Do.
XI	0.24	...do	0.27	Southward	0.12	Southward	0.89	...do	1.24	...do	0.39	Southward.

TABLE No. 12.—*Currents at different depths in the Hudson River and New York Harbor, &c.*—Cont'd.

Lunar hours.	Station off Castle Garden, June 22, 23, 1859.						Station off Forty-first street, Hudson River, Sept. 4, 5, 1858.					
	Velocity at surface.	Direction.	Velocity at 23 feet.	Direction.	Velocity at 39 feet.	Direction.	Velocity at surface.	Direction.	Velocity at 12 feet.	Direction.	Velocity at 34 feet.	Direction.
0	1.20	Southward	0.84	Southward	0.43	Southward	0.75	Southward	0.71	Southward	0.40	Southward.
I	1.73	....do	1.25	....do	0.69	....do	1.62	....do	1.60	....do	0.98	Do.
II	1.75	....do	1.52	....do	0.15	....do	2.15	....do	2.18	....do	1.44	Do.
III	1.69	....do	1.63	....do	0.22	....do	1.96	....do	2.04	....do	0.66	Do.
IV	1.44	....do	1.09	....do	0.43	Northward	1.45	....do	1.30	....do	0.07	Northward.
V	0.98	....do	0.37	....do	0.41	....do	0.58	....do	0.38	....do	0.98	Do.
VI	0.62	....do	0.45	Northward	0.47	....do	0.60	Northward	0.74	Northward	0.86	Do.
VII	0.20	....do	1.17	....do	0.55	....do	0.01	....do	0.71	....do	....	
VIII	0.11	....do	1.42	....do	0.90	....do	1.12	....do	1.52	....do	1.19	Northward.
IX	0.17	....do	1.16	....do	0.65	....do	1.10	....do	1.46	....do	1.02	Do.
X	0.44	....do	0.37	....do	0.30	....do	0.89	....do	1.06	....do	0.65	Do.
XI	1.20	....do	0.72	Southward	0.19	Southward	0.22	....do	0.22	....do	0.04	Do.

NOTE.—A diagram, C, accompanies this table.

ED. H. FOOTE, *Computer.*

TABLE No. 13.—*Specific gravities of water in the Hudson River at and below the surface, reduced to temperature of* 60° *Fahrenheit.*

SEPTEMBER, 1871.

Distance from Sandy Hook.	Station.	End of flood-current.			End of ebb-current.		
		Surface.	Below.		Surface.	Below.	
		Specific gravity.	Depth.	Specific gravity.	Specific gravity.	Depth.	Specific gravity.
Nautical miles.			*Feet.*			*Feet.*	
17¼	Off Twentieth street	1.0198	57	1.0206	(1872) 1.0141	53	1.0181
34½	Off Dobb's Ferry	1.0024	30	1.0114	1.0013	30	1.0022
38¾	Off Tarrytown	1.0021	30	1.0089	1.0016	30	1.0076
43¼	Off Teller's Point	1.0011	30	1.0087	1.0013	30	1.0087
49¼	Off Verplanck's Point	1.0012	30	1.0034	1.0014	30	1.0014
53¼	Off Iona Island	1.0017(?)	30	1.0037	1.0012	30	1.0012
56¾	Off Denning's Landing	1.0016	....	1.0028	1.0012	....	1.0021
61	Off Cold Spring	1.0015	30	1.0026	1.0010	....	....
65	Off New Windsor	....	....	....	1.0006	....	....
70¼	Off Carthage	1.0003	48	1.0016	1.0006	48	1.0012
75	Off Barnegat	1.0006	60	1.0006	1.0006	60	1.0006
79¼	Off Poughkeepsie	1.0007	48	1.0007	1.0006	48	1.0005

H. L. MARINDIN, *Computer.*

TABLE No. 14.—*Currents of East River, at Wall street, grouped according to lunar hours, not corrected for tide.*

Lunar hours.	Eastern station.	Middle station.	Western station.	Remarks.
	Nautical miles.	*Nautical miles.*	*Nautical miles.*	
0	−1.07	−3.40	−3.60	Distances of stations from Harbeck's wharf:
I	−0.38	−3.20	−3.50	Eastern station, 350 feet.
II	+0.36	−2.20	−2.75	Middle station, 842 feet.
III	+0.50	+0.10	−0.30	Western station, 1,320 feet.
IV	+1.15	+1.25	+0.80	Gig station, 1,700 feet.
V	+1.70	+1.95	+1.50	To pier No. 16, New York, 2,000 feet.
VI	+2.10	+2.22	+1.30	
VII	+1.70	+2.40	+2.00	
VIII	+1.50	+2.05	+1.20	
IX	+0.80	+0.65	+0.15	
X	−1.00	−2.60	−2.60(?)	
XI	−1.46	−3.20	−3.10	

Velocity 60 feet from pier 16, IV^h XXX^m = 0.30 nautical mile.
Velocity at Gig station, 0^h = 3.00 nautical miles.
Velocity 40 feet from pier 16, at I^h = 1.45 nautical miles.
Velocity 60 feet from pier 16, at I^h = 1.90 nautical miles.

H. L. MARINDIN, *Computer.*

TABLE No. 15.—*Volumes passing through East River at Wall-street section.*

	Distance from Harbeck's wharf.	Mean depth.	Area of section.	Velocity of stream per hour.	Duration.	Volume.
	Feet.	*Feet.*	*Sq. feet.*	*Feet.*	*h. m.*	*Cubic feet.*
Flood—eastwardly drift	0 to 400	43.6	17,440	4,260	7 15	538,600,000
	400 to 800	44.9	17,960	8,520	7 15	1,109,400,000
	800 to 1,200	48.3	19,320	9,129	7 0	1,234,600,000
	1,200 to 1,600	51.7	20,680	7,912	6 45	1,104,500,000
	1,600 to 2,000	40.4	16,160	3,652	6 0	354,000,000
		45.8	91,560	6,695	6 51	4,341,100,000
Ebb—westwardly drift	0 to 400	41.6	16,640	1,826	5 0	151,900,000
	400 to 800	42.5	17,000	7,304	6 0	745,000,000
	800 to 1,200	45.9	18,360	11,626	6 10	1,316,000,000
	1,200 to 1,600	49.4	17,760	11,868	6 10	1,446,000,000
	1,600 to 2,000	38.0	15,200	7,730	6 10	724,600,000
		43.5	86,960	8,071	5 54	4,383,500,000
Mean of flood and ebb						4,362,300,000

Ratios of scour, (varying with v^2.)

Extreme .... 1 against 1.7.
Mean .... 1 against 1.5.

H. MITCHELL, *Computer.*

TABLE No. 16.—*Mean low-water sections,* (2.21 *on staff at Governor's Island.*)

1872.

North River, at Forty-second street, gas-house pier-end.			East River, at Wall street, end of Harbeck's wharf, Brooklyn.		
Distances, in feet, from Forty-second street wharf.	Depth at mean low water.	Remarks.	Distances, in feet, from Harbeck's wharf.	Depth at mean low water.	Remarks.
0	18.5	Bowditch gig, 95 feet from Forty-second street wharf.	0	22.0	Harbeck's wharf.
100	20.0		100	47.2	
200	22.0		200	45.5	
300	24.0		300	42.7	Schooner Hassler, 350 feet from Harbeck's wharf.
400	29.7		400	40.5	
500	32.5		500	40.0	
600	34.7		600	41.0	
700	35.5		700	42.3	
800	36.2	Schooner Bowditch, 800 feet from Forty-second street wharf.	800	43.0	Steamer Arago, 842 feet from Harbeck's wharf.
900	36.0		900	44.4	
1,000	35.5		1,000	43.5	
1,100	35.5		1,100	45.3	
1,200	35.5		1,200	48.0	
1,300	35.7		1,300	48.6	Bowditch gig, 1,320 feet from Harbeck's wharf.
1,400	35.7		1,400	48.0	
1,500	35.7		1,500	48.4	
1,600	36.0		1,600	47.5	
1,700	36.2		1,700	42.5	Gig station, 1,700 feet from Harbeck's wharf.
1,800	36.2		1,800	37.0	
1,900	37.5		1,900	30.9	
2,000	37.7		2,000	25.4	End of pier 16, New York.
2,100	38.0				
2,200	39.0	Steamer Arago, 2,200 feet from Forty-second street wharf.	Mean..	41.6	
2,300	41.0				
2,400	44.0				
2,500	45.2				
2,600	45.7				
2,700	46.5				
2,800	47.2				
2,900	47.5				
3,000	47.2				
3,100	46.0				
3,200	44.5				
3,300	38.0				
3,400	32.0				
3,500	26.5				
3,600	24.0				
3,700	20.0	Schooner Hassler, 3,700 feet from Forty-second street wharf.			
3,800	14.0				
3,900	10.0				
4,000	5.7	Hassler's gig, 3,900 feet from Forty-second street wharf.			
4,100	4.0				
4,200	2.0				
4,300	1.2				
4,400	0.5				
4,500	0.0	End of line at Jersey shore.			
Mean..	30.34				Mean rise..................... 4.3

H. L. MARINDIN, *Computer.*

TABLE No. 17.—*Currents of Hudson River off Forty-second street, September 13 and 14, 1872.*

Civil time.	Eastern station. Velocity.	Middle station. Velocity.	Western station. Velocity.	Civil time.	Eastern station. Velocity.	Middle station. Velocity.	Western station. Velocity.
h. m.				h. m.			
Sept. 13 13 30....	....	....	+ 0.15	Sept. 13 3 0....	− 0.80	− 0.80	− 0.15
14 0....	− 0.25	....	+ 0.55	3 30....	− 0.47	− 0.47	+ 0.02
14 30....	+ 0.15	+ 0.10	+ 0.75	4 0....	− 0.20	− 0.20	+ 0.17
15 0....	+ 0.45	+ 0.62	+ 0.95	4 30....	+ 0.15	+ 0.15	+ 0.42
15 30....	+ 0.80	+ 1.00	+ 1.10	5 0....	+ 0.37	+ 0.37	+ 0.70
16 0....	+ 1.32	+ 1.60	+ 1.25	5 30....	+ 0.47	+ 0.60	+ 1.00
16 30....	+ 1.60	+ 1.90	+ 1.17	6 0....	+ 0.50	+ 0.90	+ 1.00
17 0....	+ 1.65	+ 2.00	+ 1.10	6 30....	+ 0.47	+ 1.05	+ 0.92
17 30....	+ 1.50	+ 1.92	+ 1.05	7 0....	+ 0.25	+ 0.90	+ 0.77
18 0....	+ 1.32	+ 1.80	+ 1.05	7 30....	0.00	+ 0.65	+ 0.48
18 30....	+ 1.05	+ 1.65	+ 0.95	8 0....	− 0.15	+ 0.40	+ 0.15
19 0....	+ 0.70	+ 1.40	+ 0.52	8 30....	− 0.30	− 0.10	− 0.17
19 30....	+ 0.05	+ 0.92	+ 0.20	9 0....	− 0.75	− 0.75	− 0.55
20 0....	− 0.40	+ 0.45	− 0.15	9 30....	− 1.20	− 1.20	− 1.00
20 30....	− 0.75	− 0.25	− 0.62	10 0....	− 1.65	− 1.65	− 1.25
21 0....	− 1.05	− 1.05	− 0.90	10 30....	− 2.00	− 2.00	− 1.45
21 30....	− 1.65	− 1.65	− 1.25	11 0....	− 2.42	− 2.42	− 1.52
22 0....	− 2.00	− 2.00	− 1.45	11 30....	− 2.60	− 2.60	− 1.45
22 30....	− 2.35	− 2.35	− 1.50	12 0....	− 2.65	− 2.65	− 1.25
23 0....	− 2.65	− 2.65	− 1.42	12 30....	− 2.57	− 2.57	− 1.05
23 30....	− 2.57	− 2.90	− 1.35	13 0....	− 2.30	− 2.30	− 0.85
0 0....	− 2.40	− 2.85	− 1.37	13 30....	− 2.00	− 2.00	− 0.57
0 30....	− 2.30	− 2.47	− 1.25	14 0....	− 1.52	− 1.52	− 0.38
1 0....	− 2.25	− 2.25	− 1.10	14 30....	− 1.00	− 1.00	− 0.20
1 30....	− 2.00	− 2.00	− 0.67	15 0....	− 0.35	− 0.35	+ 0.20
2 0....	− 1.65	− 1.65	− 0.45	15 30....	+ 0.30	+ 0.30	+ 0.55
2 30....	− 1.30	− 1.30	− 0.30				

Sketch D illustrates these tables.

Distances of stations from Gas-house wharf:

Gig station	95 feet.
Eastern station	800 feet.
Middle station	2,200 feet.
Western station	3,700 feet.
Gig station	3,900 feet.

Grouped according to lunar hours.

Lunar hours.	Eastern station. Velocity.	Middle station. Velocity.	Western station. Velocity.	Lunar hours.	Eastern station. Velocity.	Middle station. Velocity.	Western station. Velocity.
0	− 1.37	− 1.39	− 1.10	VI	− 0.09	+ 0.14	+ 0.35
I	− 2.32	− 2.15	− 1.47	VII	+ 0.74	+ 0.89	+ 0.85
II	− 2.63	− 2.72	− 1.35	VIII	+ 1.05	+ 1.24	+ 1.05
III	− 2.35	− 2.46	− 1.12	IX	+ 0.85	+ 1.35	+ 1.00
IV	− 1.82	− 1.83	− 0.40	X	+ 0.22	+ 0.98	+ 0.36
V	− 0.93	− 0.83	− 0.01	XI	− 0.50	− 0.04	− 0.40

Velocities:

At Gig station, 95 feet from wharf:

At VIII^h	+ 0.55
At I^h	− 1.25
At II^h	− 1.10

Gig station, 3,900 feet:

At VIII^h	+ 0.67
At IX^h	+ 0.50
At II^h	− 0.70

H. L MARINDIN, *Computer.*

APPENDIX No. 9.

REPORT TO PROF. BENJAMIN PEIRCE, SUPERINTENDENT UNITED STATES COAST SURVEY, CONCERNING NAUSETT BEACH AND THE PENINSULA OF MONOMOY.

In the autumn of 1870, during a violent easterly gale, a breach was made by the sea through the Nausett Beach, nearly opposite the Chatham south light, and the sea, driving through, attacked the water-front of the town. A short time after this event I received notice to join you in a visit to the neighborhood, accompanied by Rear-Admiral Charles H. Davis, and Prof. H. L. Whiting; and after reaching Chatham, we held a consultation with a view to making a little investigation into the tendencies of these changes along this portion of the coast. The result of our conference was, that you ordered me to make surveys from time to time, and report.

With this order I have complied, as well as I could with so many other duties, and this is my first report, in which I shall deal with facts only, leaving all discussion of causes till we learn more about them.

PHYSICAL HISTORY OF THE NEIGHBORHOOD OF CHATHAM.

The history of this portion of our coast really begins with Captain Champlain's narratives, (1606.) It is true that we find some confused references to it in Archer's account of Gasnold's voyage, made some three or four years earlier, but there is in this account nothing *shipshape;* and I am convinced that Archer formed no conception of the lay of the land.

It is possible that the expedition may have approached and left "Elizabeth Isle" by different routes; in one case, passing through the sounds; in the other, going round the seaward islands and shoals, and that the narrator confounds the objects seen in these two voyages. For instance, on the 21st of May they seem to have entered Nantucket Sound from the *eastward*, and speak of the main-land as trending southwestward; on the same day they fell in with No-Man's Land, which they call Martha's Vineyard—a "*disinhabited*" island, where they saw "fast running thirteen savages apparelled as aforesaid," and after lying three days in a place that I know from experience to be a very rough and dangerously exposed anchorage, they entered Vineyard Sound from the *westward!*

The parties of Champlain made two visits to Cape Cod, in the first of which they ran across from Port St. Louis, (Plymouth,) and in the second from "Cap St. Louis," described as lying two leagues from the aforesaid port. In both trips they doubled the cape, and ran down the outer coast, but in the first only as far as Malle Barre, (Nausett Inlet,) where they found a *bad bar* at the entrance just as at the present day.

From the narrative of the second trip I quote the following passages:*

* * * "The last of September we left Beauport, passed Cap St. Louis, and ran all night for Cap Blanc. In the morning, an hour before day, we found ourselves to leeward of Cap Blanc, in the Bay Blanche, in eight feet of water, one league from the shore, where we came to anchor in order not to get too near while waiting for daylight, and to see how the tides were. Nevertheless, we sent out our boat to sound, and found no more than eight feet of water, so that it was necessary to consider before daylight what we ought to do. The water diminished even to five feet, and the heel of the vessel touched the sands, albeit without doing herself injury; for the sea was smooth, and not less than three feet deep beneath us, when the tide began to rise, which gave us good hope."

"At daybreak we perceived a very low sandy shore, toward which we dragged further down to leeward, whence we sent a boat to sound towards a pretty high knoll, where they judged there would be plenty of water, and in fact they found there seven fathoms. We anchored there, and at once equipped the boat with nine or ten men to go on shore to see a place where they judged they should have a good shelter, if the wind should blow up stronger than it was. The search being successful we carried in two, three, and four fathoms of water, and found five or six fathoms after we got in.

* From "Œuvres de Champlain, publiéessou s le patronage de l'Université Laval, par l'Abbé C. H. Laverdiére, M. A., Professeur d'Histoire," &c.

There were plenty of oysters, which were very good, which we had not observed before, and we named the place Oyster Harbor, and it is in 42° of latitude. There came to us three canoes of savages. The wind came out fair in the course of the day, which induced us to quit our anchorage and to go to Cap Blanc, distant from this place five leagues to the north a quarter northeast, and we doubled it."

"The next day, 2d October, we were off Malle Barre, where we were detained sometime by head winds, during which Mr. Pritrincourt, with the boat and twelve to fifteen men, visited the harbor, where there came before them one hundred and fifty savages, singing and dancing in the usual way. After having seen this place, we returned to our vessel, and the wind coming fair we sailed along shore running southward."

Having come to the close of the author's chapter, I will pause in my quotation to discuss a little the narrative thus far.

Beauport, from which they started, was Gloucester, of which a pretty good chart is given, with the depths the same as now. Cap St. Louis was possibly Cohasset, but more likely Gurnet Point, which is a promontory, *apparently* projecting far beyond the adjacent land, which is low. This point (as I make it) was the of the Northmen, and "Poynt George" of Capt. John Smith.

They ran through the night for Cape Cod, which had received the name of Cap Blanc in the previous voyage, "by reason of its white dunes," which are very remarkable in the Province Lands. They did not fetch so far to windward as they expected, and so got down on the Billingsgate Shoals, where they found eight feet of water at low tide—just as now.

After daylight they worked their way to the northward into seven fathoms water, off Great Island, perhaps; whence they sent a sounding party into Wellfleet, the entrance to which is just about five leagues from the extremity of the cape, although in lower latitude (some 10′) than given in the narrative.

The depths mentioned are much the same as our present charts give. In the previous voyage they had got down into the bight of the bay much in the same way, but then it was because (as they state) they thought the forearm of Cape Cod was an island. It has that appearance, and, I think, the Northmen, six hundred years before, made precisely the same mistake, and that the "*island lying north of the main-land*," seen by Leif, was the same. Thorfinn Karlsefue, coming afterwards from the north, fell to the southward of the end of the cape outside, but believing it to be an island he attempted to go around the south end. These Northmen called the cape Kiarlness, after the land-mark (the old keel of his ship) set up by Thorwald Ericson. Capt. John Smith named the same point Cape James; some years after Gosnold had given it the name it now bears, Cape Cod.

The editor of this Quebec edition of Champlain makes the port, reached on the 1st of October, Barnstable, perhaps because it better suits the present bearing of Cape Cod, and he adds that "it seems to have bequeathed its ancient name to a portion of the present port, which is called Oyster Bay." Barnstable is in 41° 43′, and distant from the extremity of the cape about twenty-one nautical miles. Our Coast-Survey chart of Barnstable mentions no Oyster Bay, but I need not go far off in any direction to find the word oyster applied in various ways.

Malle Barre was sketched on the previous voyage, so that we may be pretty sure that it was the present Nausett. The opening among the hills seems to promise, as seen from sea, a good port; but, on near approach, the mouth of the bay is nearly closed by a sand-beach, through which there have never been safe inlets.

It was into this place, I think, that Thorfinn Karlsefue ventured in the hope of getting through to Vinland. He seems to have subsequently gone up to Nantucket Sound, and, as he states, found himself to the southward of Vinland, which (as I make it) lay on the west shore of Cape Cod Bay, where the "*high tides*" were found.

As far as I know, this name, Malle Barre, is the only one from Champlain that has survived in Massachusetts; and even this showed at one time a disposition to slip off. As early as 1640 it had left Nausett, and appears in the Atlas Novus (a book of Dutch maps, accompanied by Latin text) at the elbow of the cape in copartnership with Ulackehoek.* The old name has gone out of popular use, but still appears on our latest Coast-Survey chart attached to Monomoy Island.

* Upon this map Nantucket is called Vlieland, and is joined to Martha's Vineyard, which is called Texel. Nantucket Sound is called Zuyder Zee.

"*Continuation of aforesaid discoveries, and what they noticed remarkable. Chapter XIX.*—As we got some six leagues from Malle Barre, we let go the anchor near the coast, because we had no wind. Along these parts we descried the smoke which the savages made, which made us think of going to see them; so to this end we equipped the boat. But when we came near the shore, which is arenaceous, we could not land because the breakers were too high. The savages, seeing this, launched a canoe, and came to us, eight or nine of them, singing and making signs of joy that they felt at seeing us, and showed us that lower down there was a port where we could find safety for our vessel. Not being able to land, the boat returned to the vessel, and the savages, who had been treated humanely, returned on shore.

"The next day, the wind being favorable, we continued our route to the north (?) five leagues, and had no sooner made this distance than we found three and four fathoms of water, being a league and a half from the shore. Going on a little farther the bottom rose suddenly to a fathom and a half and two fathoms, which frightened us, seeing that the sea broke everywhere without our seeing any passage by which we could return upon our road, because the wind was contrary. We were involved in such fashion among the breakers and sand-banks that it was necessary to pass at all hazards, according as one might judge of where lay the best water for our vessel, which was only four feet at most, and we came among the breakers up to four and one-half feet.

"Finally we succeeded, by the grace of God, in passing over a point of sand which juts out three leagues to the south-southeast, a very dangerous place.

"Doubling this cape, that we named Cap Batturier, which is twelve to thirteen leagues from Malle Barre, we came to anchor in two and one-half fathoms, inasmuch as we saw around us everywhere breakers and shoals, except in some places, where the sea was not breaking very much. We sent a boat to find a channel, in order to go to the place that we judged to be the place that the savages had told us about, and believed that there was a river where we could be in safety.

"Our boat arriving there, our men went ashore, and considered the place, and then returned with a savage, that they brought off, who told us that at high water we could get in, which we resolved to do, and immediately got up anchor, and were conducted by the savage, who piloted us to cast anchor in a roadstead in front of the port, having 6 fathoms of water and good bottom, for we could not get inside, because overtaken by the night.

"The next day we sent and put marks on the end of a bank of sand, which is at the embouchure of the port, and then high tide coming on we ran in with two fathoms of water.

"Having got there, we praised God that we were in a place of safety. Our rudder had been broken, and tied up with cords, and we feared that among the shallows and strong tides it would be broken again, which would have caused our loss.

"Within this port there is only one fathom at low water, and two fathoms at high water. To the eastward there is a bay which runs up to the northward some three leagues, in which there is an island and two other little bays, which diversify the country, where there is a good deal of cleared land and many small hills, where they cultivate corn and other grains, upon which they live. They have also very fine grapes, quantities of hickory, oaks, cypress, and a few pines. All the people in this place are very fond of agriculture, and make provision of Indian corn for the winter. * * * This would be a very proper place to found a republic if the port was a little deeper and the entrance more sure than it is.

* * * "Nevertheless, we sent a boat with five or six men and a savage to see if they could find a better passage to go out than that by which we had come. Having made five or six leagues and landed, the savage ran away. * * * When they returned they reported to us that as far as they had been there was at least three fathoms of water, and that beyond there were neither banks nor shallows. * * * The 16th of the month we left Port Fortuné, which we had so named for the unhappy circumstances which had befallen us there. It is in latitude 41½°, and some twelve or thirteen leagues from Malle Barre."

From the first clause of the foregoing chapter, it would appear that after passing Nausett they made another landing on the open coast *before getting beyond the limits of cultivated lands.* The distance given is evidently an overestimate, since so long a run directly south would have taken

them to Monomoy Island, which is only a strip of beach sand. Moreover, when we consider that in the early part of the day, while "detained some time by head winds," they had assisted at a dance on shore, and in the latter part of the day had come to anchor in a calm and gone in their boat to meet the savages again, there would not seem to be much time left, in the light of an autumn day, to make all these leagues. So I conclude that night found them at anchor above Chatham, and that the next day's run was to the *southward* over the Pollock Rips, Shovelfull, and other shoals of Monomoy, and *northward* up the west shore of Monomoy into the roadstead of Old Stage Harbor. The distance is again overestimated, but not more so than I have often been prone to myself when running along a beach which offered to the eye no objects by which to mark our progress. The sudden coming upon shoals wide out from a shore that everywhere above had proved quite bold and free is narrated quite graphically, and any sailor who has been so unfortunate as to get among the Monomoy Shoals will appreciate the hazard of attempting to double the point within the banks.

Of course, the shoals and beaches have shifted very much and often since this strange little vessel of four feet draught braved their dangers, but we know from our studies of such shoals that the relative order of banks and beaches remains about the same, however the system as a whole may change its location.

The estimated length of the point of sand which he calls Cap Batturier, (Cape Shallow,) which is, of course, our Monomoy, proves quite correct; but I shall hereafter show that this is proving a little too much, because this feature in the physical geography of our coast has been rather steadily growing since we have known it intimately by the light of good surveys.

The editor of the narrative under review interprets Cap Batturier to be Sankaty Head, Nantucket, in order, I suppose, to accommodate the distances stated. Sankaty Head is no more entitled to be called a "*point of sand*" than Bunker Hill, which is geologically of the same formation; and how a vessel coming from the north can double Sankaty Head and reach Chatham Roadstead the same day, via Muskegat Channel or round the Vineyard, I cannot see.

Chatham Roadstead, called on our Coast-Survey maps Old Stage Harbor, is a good place in northerly and easterly gales, but with very strong southwesterly winds it is not safe even for able and well found vessels.

The ancient and recent charts of Chatham, which we have given side by side in the sketch that accompanies this paper, resemble each other sufficiently to leave no doubt of identity; but still, by reason of very recent changes in the sand beach (the Lido in front of the promontory of Chatham) the likeness is not now so striking as it would have been if we had compared the ancient map with one of our previous surveys.

It will be observed that the ancient map is not properly oriented; it is, in fact, swung out to the westward some 20° from the true meridian. I am surprised at this, because on the previous voyage the variation of the compass had been determined at Malle Barre, and found to be 18° 40′ W. Subsequent observations have shown that the declination declined through the whole of the eighteenth century, falling as low as 6° 30′ W. at Cambridge University, while the present century shows a steady increase, so that now the declination at Cape Cod is about 11° W. Champlain has a good deal to say about the variation of the compass, and explains with a diagram his manner of laying out a meridian line, which is good.

The latitude given in the narrative for Port Fortuné, "forty-one and one-third degrees," is too low by about twenty minutes, while that given for "Beauport," "forty-three," is about as much too high. The distances measured by its run scale of *toises* upon the map of Port Fortuné are very wild; the map has a twist, showing that it is, in great measure, prospective, corrected by estimated distances.

Notwithstanding all these defects, there is something very *real* about the picture as it appears in its original form, with its hills and fields—more real, in fact, than our modern map. I have often thought, when looking at Chinese, Japanese, and old Dutch maps, in which appear the likenesses of real hills and trees upon the land and fishes in the sea, that I should much more easily recognize the scenes if I were to visit them, after seeing such representations, than by the use of our modern topographical maps; and I believe that if the officers of Champlain, while at Port Fortuné, had in prophetic vision seen our Coast-Survey plane-table sheet of Chatham, with all its conventional, if not arbitrary, signs, they never would have dreamed what it meant. But our maps are not designed

to furnish simply the means of recognition, or even a guide to navigation only. They are required to supply some of the wants of civil and military engineers, of geologists, agriculturists, &c., &c. To meet these wants, with the requisite economy of space, a technical language has been resorted to, which is not so artificial as the signs of mathematics, and almost as universal.

This brings me to the consideration of the popular legend concerning a lost island which lay wide out to sea off Chatham. As far as I can learn, the story first appeared in print in the Massachusetts Magazine, and bears the date of December 1, 1790. It runs thus:

"When the English first settled upon the cape, there was an island off Chatham, three leagues distance, called Webb's Island, containing twenty acres, covered with red cedar or savin. The inhabitants of Nantucket used to carry wood from it. This island has been wholly washed away for almost a century. A large rock that was upon the island, and which settled as the earth washed away, now marks the place. It rises as much above the bottom of the sea as it used to rise above the surface of the ground. The water is six fathoms deep on this spot."

Mr. Chapin, to whose report I shall refer more particularly hereafter, mentions that "stumps bearing the marks of the axe still come on shore at Chatham."

The English Coast Pilot, 1707, has a map of Nantucket Sound and shoals, which contains the name "Webb's Island," extending from the flats below Chatham. No island is represented, or any shoal ground, except the flats aforesaid. No mention is made of it in the sailing directions. There are three other islands off the point of Monomoy, called Seale Isles on this chart, which do not exist, but whose sites are dangerous shoals to-day, which run dry in spots.

Let us agree that a "Webb's Island" did exist; it remains to inquire whether it was a projecting part of the cape or really a separate land. The tradition says there was a rock on it, so we may conclude that it was upland (drift formation) and not a broken piece of beach. If the distance, "three leagues," is correct, it was separate, because at this distance from the land (whether we take Chatham of 1606 or 1872) there are 35 to 40 fathoms of water. If this distance was wrong (as such measures on the sea usually are in such traditions) but the depth (6 fathoms) correct, we may plot the island within 3,000 feet of points in Chatham which have remained permanent since the discovery of the continent. The six-fathom line hugs the shore now within 2,000 feet at many points.

Champlain's map of "Nouvelle Franse" does not give this island, although his officers made two trips down the coast of Cape Cod, and, on the second, passed this place a league and a half off shore. These officers speak of Monomoy and the shoals, but do not mention an object which, if it had existed, would have been represented by them as a terror.

Again, it is said that the Nantucket people took wood from this island. Is it at all likely that they would have gone out, passed the Handkerchief, Shovelful, Stone Horse, and the Pollock Rips, to an unsheltered island in the ocean, thirty-five miles from home, when they could have got all they wanted from Cotuit, Hyannis, and other points, from which they have brought wood within my knowledge? They had, in the early part of the eighteenth century, as also in the larger part of this, a passageway inside of the beach from Nantucket Sound all the way up to Pleasant Bay, above Chatham; and some island accessible from this inside passage may have been visited for wood. Nantucket was settled in 1660, and the town of Sherburne incorporated 1687; at which time accounts state that the place was wooded, so we may presume that they were not driven to importing fuel till one generation at least had passed, before which time the strange island had gone down like the Royal George—nor do we find the stone that marks its grave.

Of course, I do not deny that great encroachments are being made by the sea wherever the uplands are exposed to the attacks of the waves. I say *upland*, because wherever a skirting of alluvial beach is found the work of destruction becomes intermittent or ceases. And by *upland* I mean the glacial drift, (so called,) which, if we may judge from the underlying beds of shells in some cases, is itself an intruder upon the original domain of the sea.*

The very locality now under special examination affords a striking case of very recent

* The above had been written before I knew of Mr. Otis's account of the discovery of an ancient ship on the eastern shore of Cape Cod, which I have read with great interest and some dissent. As the locality of the wreck is above the reach of our present surveys, I propose to reserve all comment on this matter till I can sound along the shore very carefully next season.

encroachment by the sea. Upon our two little maps of Chatham (see Sketch No. 35) you will observe that the letter G in one case stands for an "*Isle remplis de bois*," and in the other for the site of Ram Island, (washed away.) It is difficult to determine how much of an island this was in 1606, because the Champlain map will not bear nice application of its own scale, but it may have been a hundred acres. It was at that time protected from the sea by the beach. Upon our first topographical map, that of Mr. Glück, in 1847, this island is still found, with an area of thirteen acres, an elevation of twenty feet at several points, and a house or building of some kind upon it. Its situation relative to the ocean had changed; a broad inlet had opened directly before it, and exposed it to the fury of the storm-waves. Mr. Marindin, from recent inquiry at Chatham, learns that this island had been used as a pasture down to 1851, when the remarkable Minot's gale essentially closed its history. Traces of it remained for several years, but Messrs. Adams and Marindin, who made a topographical survey thereabout in 1868, saw nothing of it.

But the neighborhood of Chatham has not been, generally, one of great change since the time of Champlain, except in the continual shiftings of the *littoral cordon* of sand which skirts the shore. Upon each of our little diagrams of Chatham (see Sketch No. 35) you will observe a pond marked E. It is a fresh pond in a hollow of the upland, and *is no nearer the water now than it was two hundred and sixty-six years ago*, although the ocean has swept away and re-formed the beach in front repeatedly.

This strip of beach is familiar as a physical feature, and falls under the general designation of the *littoral cordon*, a name which was applied to it by M. Elie de Beaumont in his *Géologie pratique*.

Upon the New England coast it appears only here and there in a sporadic way, but below Montauk Point, Long Island, it is the characteristic feature all the way to Yucatan.

I have discussed this formation somewhat at length in my article on the "Reclamation of tide-lands," and shown in what manner it appears as the residual deposit after the sifting of the material torn from the coast by the waves.

Although it is prone to shift its position and change its form, its presence, on the whole, betokens a check in the conquest of land by the sea. In the instance before us there would seem to have been a general falling back of the cordon since 1606, but if we compare the two charts by using the distance from the pond E to the south end of Morris Island as a base, the change is not large. I see no positive indication that the *cordon* is undergoing final destruction, although I cannot find that at any previous period its area has been so small as now.

The map of 1606 shows a passageway between Morris Island and the main-land, and I find that the closure of this strait occurred between 1752 and 1772.* This "island" is upland (drift) and is connected now by a *sandy cordon* with the adjacent uplands of the main-land. This sandy cordon has blown up into dunes, and a salt-marsh has formed in the rear of it, over a channel which used to be navigable. Mr. Marindin learned, while recently in Chatham, that traditions of this strait were quite familiar among the people, and that the last vessel that attempted the passage was a pinkey schooner. The closure resulted from the falling back of the beach; and upon Des Barres' map of 1764 Monomoy appears as a peninsula extending southward from Morris Island and the main-land.

Monomoy is a projection of the *littoral cordon*, and has evidently been built of materials torn from the cape-shore, and its seaward aproning, under the attacks of a northeast sea, and is, therefore, very modern in a geological sense, but not recent, I think, from a historical point of view, as my accomplished young friend, H. N. Chapin, has presumed it to be in a recent communication. It appears as a triangular shoal or dry flat upon Champlain's maps, and was referred to in the narrative quoted above quite distinctly. A century later it appears upon the chart of the English Coast Pilot as a large and broad island, and in the sailing directions it is said to lie "from the tail of the Horse Shoe about nine leagues ENE." Its point now lies NE. by E. ½ E., (true,) eleven and three-fourths miles from the same place.

As no part of Monomoy could be seen from the Horse Shoe, and as the distance was a matter of longitude, it is not remarkable that the estimate should be very wild. If we suppose the sailing-course correct by compass, (of which the variation is stated to be 10°,) Monomoy was about a mile and a quarter shorter in 1707 than it appears upon our first survey by Mr. Gilbert, (1853.)

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* Massachusetts Historical Collection.

In the "Description of Barnstable," (1802,) published in the Massachusetts Historical Collection, the location of a humane house is carefully stated to be "four miles from the end of Monomoy Point, and six miles from Chatham Great Hill, which bore N. by W." Plotting this upon our chart, with bearing corrected for variation, it appears that the house was situated close to the present outside shore-line near Wreck Cove, Monomoy Island, and that the point of the beach lacked but a quarter of a mile of being as far out in 1802 as in 1853, (the date of our first Coast Survey topographical sheet.) In this paper of 1802 it is stated that the beach has been "continually gaining during the past fifty years."

Of course, there are plenty of maps extant which give different testimony, some of them published this very year; but all evidence is ruled out which is not from sources the mariner would respect, because to him and his protectors only had this worthless strip of beach the slightest significance. It was to him a terror, and chart-makers as well as humane societies made themselves familiar with its location.

Since 1853, Monomoy has been advancing with great rapidity into Nantucket Sound, the point moving out at the rate of 138 feet per annum between 1853 and 1856, and 157 feet per annum between 1856 and 1868. Like Sandy Hook, a similar formation at the mouth of New York Harbor, this peninsula of Monomoy seems to have made alternately long pauses and rapid strides in its progress seaward.

If this movement should continue till it passes on to the Handkerchief Shoal, a grand harbor of incalculable value may be created in place of the little Powder Hole, which has recently ceased to be. A movement similar to this, no doubt, formed the grand harbor of Provincetown at the extremity of the cape, and I refer you to Prof. H. L. Whiting's report of 1867 for very interesting remarks concerning it.

The first mention of a harbor in the peninsula of Monomoy that I find is in the "Description of Barnstable" before mentioned. It is called "Stewart's Bend," and is said to afford safe shelter in three or four fathoms. The word "bend" indicates that it received its name before it was actually a harbor—while it was only a hook. In my boyhood the Powder Hole was considered a very valuable harbor of refuge, but when I ran into it with the Coast-Survey schooner Bowditch in 1856, forty fishing-vessels, which lay there at anchor, packed it nearly full. Three fathoms at low water could be carried into this snug little place when our chart of 1854 was issued, but Mr. Chapin found but two feet at the time of his recent visit.

RECENT MOVEMENTS OF CHATHAM BEACH IN DETAIL.

Since the consultation held at Chatham in the autumn of 1872, Mr. Marindin has made one regular plane-table survey in January, and a compass-survey during the present month. I quote the following clauses from his report to me of December 10:

"Since our survey of Chatham Beach in January, 1872, many changes have occurred, which I have noted in my last visit to this place on the 6th of December, 1872."

"The two inlets, one known as the North Inlet, into what was called Old Harbor, at the southern extremity of Pleasant Bay, and the inlet which was made November 15, 1871, during an easterly gale, nearly opposite Chatham lights, still exist. The former does not appear to have changed, but the latter has altered materially. The south end of the beach, (north end of opening of November 15, 1871,) which in January last had been thrown nearly midway into the harbor, has gradually extended in a southwesterly direction, and, curving to the westward, has joined on the main land near Chatham lights. The height of the beach, where last winter there could be found two fathoms of water, is nearly three feet above high water, with a width varying from 100 to 135 feet. The whole beach as far as the inlet of 1851, to the north, is gradually weakening and must finally be beaten in on the Chatham shore."

"The north end of the beach at this opening (now Monomoy Beach, since it is connected with Monomoy Island) has retreated to the southward, making the beach wider, as the opposite beach (at the north side of the inlet) does not seem to have followed the same course, but has turned off towards the main to the westward; and during the latter part of October last, when the north end

was nearly opposite Chatham lights, the sea again broke through this part of the beach, cutting off the end into a small island, as shown in the sketch. This island is being worn off by the sea and tidal currents, and continually thrown farther into the harbor, so that in a few weeks it may no longer exist."

"There seems to be no distinct channel through the inlet into the harbor, the whole distance across being a continuous line of breakers when visited on December 7, 1872."

"Since the formation of the inlet, (November 15, 1871,) the main shore near Chatham lights has been exposed to the sea, and consequently much worn, so that fears were entertained by Mr. C. H. Smith, keeper of the lights, from whom most of my information was obtained, of the safety of the light-houses. The line of the bluff on which the lights stand has retreated nearly one hundred feet since the new opening of last year. At the present time, however, the new position of the south end of the north beach, resting as it does on the shore near the light-houses, has strengthened the shore, so that filling in is going on at the foot of the bluffs."

"From information gathered among the old inhabitants of Chatham, we find that great changes have taken place in the shores of this part of the cape. Two hundred years ago the neck of land now connecting Morris Island with the main did not exist except as a shoaling up of the passage, and since that time tradition says that the last vessel which tried the passage was of the class known as "Pinkey," and that she grounded and failed to pass through."

We have been very much struck with the diminution in the area of the beach shown by the topographical maps since 1847, but we do not know whether this change is wholly superficial or not. I hope next season to have the opportunity to run a few normal lines of soundings for future comparisons. Mr. Marindin's comparisons of areas and distances give the following:

No. 1.—*Table of areas of Chatham Beach, between latitude* 41° 39′ *and* 41° 42′.

Between latitude—	Area of beach in the year—				
	1847.	1868.	Loss of area, 1847 to 1868.	1872..	Loss of area, 1868 to 1872.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*
41° 39′ and 41° 40′	186	147	39	113	34
41° 40′ and 41° 41′	174	71	103	35	36
41° 41′ and 41° 42′	146	49	97	39	10
			239		80

From inspection of the above table we find the loss of area of the beach between 41° 39′ and 41° 42′, from 1847 to 1872, to be 319 acres, or 63 per cent. of the area in 1847. From 1847 to 1868, the loss was 239 acres, or 47 per cent. of the area in 1847. From 1868 to 1872, the loss was 80 acres, or 30 per cent. of the area in 1868.

No. 2.—*Table of distances of eastern shore of Chatham Beach, west from meridian* 69° 55′.

On latitude—	Distance west of meridian in the years—				
	1847.	1868.	Retreat, 1847 to 1868.	1872.	Retreat, 1868 to 1872.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
41° 39′ 0″	6,475	6,075	+ 400	6,150	− 75
41° 39′ 15″	5,525	5,650	− 125	5,802	−152
41° 39′ 30″	4,925	5,275	− 350	5,595	−320
41° 39′ 45″	4,550	5,005	− 455	5,405	−400
41° 40′ 0″	4,255	4,795	− 540	5,095	−300
41° 40′ 15″	3,975	4,570	− 595	Inlet, (1871)	
41° 40′ 30″	3,625	4,285	− 660	4,635	−350
41° 40′ 45″	2,870	3,627	− 757	3,895	−268
41° 41′ 0″	2,060	3,127	−1,067	3,127	± 0
41° 41′ 15″	1,820	3,085	−1,265	3,060	+ 25
41° 41′ 30″	1,520	4,355	−2,835	5,155	−800
41° 41′ 45″	1,360	North Inlet.		North Inlet.	
41° 42′ 0″	Inlet	Inlet		Inlet	

NOTE.—Width of beach on latitude 41° 41′ in 1847 .... 1,700 feet.
Width of beach on latitude 41° 41′ in 1868 .... 590 feet.
Width of beach on latitude 41° 41′ in 1872 .... 590 feet.

The testimony of the preceding tables must not be understood as extending beyond the districts stated, because a large part of the littoral cordon on this part of the Cape Cod shore has remained unchanged since 1847.

I have already referred to a report from Mr. Chapin, aid in Mr. Granger's Coast-Survey party, touching this portion of Cape Cod. He was sent by my request to inquire into the circumstances under which the Powder Hole had been lost. He takes one of the interpretations of Archer's narrative, and gives to Monomoy a brief existence. I have no confidence in the narrative, but the physical history of Monomoy is an open question. If during the past two or three centuries the rate of growth southward has been as rapid as it has been since our surveys, there could not have been much of it in existence at the time of Gosnold's voyage. In my discussion of the case from old maps, I have concluded *for myself* that this peninsula is much older than our knowledge of the coast; perhaps not as *dry land*, however.

I do not regard the shore-line of these beaches as an important contour *from a physical point of view*, but would rather take submerged curves, for instance, the outline of the base of such a shoal upon the floor of the ocean. In the instance of Sandy Hook, New York, or Brewster Spit, in Boston Harbor, the advance is like that of a great mole building out into the sea, and it is more easily traced near the bottom, where it is not modified by causes so irregular as those near the surface. I think Mr. Granger's hydrographic survey, now in progress, will throw more light on this question which Mr. Chapin has raised. He presumes that the material which is adding to the point is from the waste of the Chatham Beach, &c. In the case of Sandy Hook, I was able by depositing materials of different specific weights, at different depths along the coast, to determine precisely whence the building materials came, (1857–'58.) I found the source of supply in the neighborhood of Long Branch, twelve miles below the point of the Hook, where the upland has no protecting cordon of sand. I shall ask Mr. Chapin to make similar experiments on the Monomoy shore.

Mr. Chapin learned that seventy-five years ago, before Monomoy extended as far as now, there were islands on the shoal beyond, and, as we knew from our charts, very shallow spots existed off the point before the recent advance. In the growth of the point, an *apparent* acceleration would take place on falling in with these. There are still some outlying dry spots, mentioned by Mr. Granger from his past summer's observations.

There is a portion of Mr. Chapin's report concerning the recent changes among the shoals,

which I should like to quote in full, because it is interesting; but as he does not give his authorities, and some of the old charts contradict him, I shall refer the matter to him again for review. When Mr. Granger's hydrographic survey is completed, these notes of Mr. Chapin's will furnish again valuable hints for the proper direction in which to make comparisons, and I expect to be indebted to him for further observations by that time.

Very respectfully, yours,

HENRY MITCHELL,
United States Coast Survey.

BROOKLINE, MASS., *December* 22, 1872.

APPENDIX No. 10.

HINTS AND SUGGESTIONS UPON THE LOCATION OF HARBOR-LINES, BY HENRY MITCHELL, UNITED STATES COAST SURVEY.

Although we have, from time to time, through many years, been called upon to advise in fixing the safe and commodious limits of encroachment upon the harbors along our coast, we should find ourselves greatly embarrassed in the attempt to lay down *rules* for future guidance, because in almost every case that has arisen occupation of the water-front has already taken place in an irregular and injurious manner, and experts have been called in not so much to undo the wrong as to stay its further progress. Nevertheless, there are certain elements that enter into the discussion of all cases, and other elements that always appear in specific classes of cases, which we propose to make the subject of this unambitious paper.

Our harbors generally.—If we run over a list of those sheltered indentations of the coast which have served us for harbors of trade or refuge we distinguish very readily two grand divisions, into which they can be more or less accurately grasped. These are *inlets*, *i. e.*, breaks through the littoral cordon of sand that skirts the coast, and arms of the sea, or *fiords*. Sharply-defined instances of the first class are quite numerous along our southern coast, and Port Royal, S. C., may be taken as a type. So of the second class we have many examples, especially along the sea-board of New England, where we may select Portsmouth, N. H., or Casco Bay as a type.

Most of our rivers find their way to the ocean through inlets and fiords. It is true that the Mississippi, scorning alike assistance and restraint, makes its way to the sea with no obstruction but its own debris; but this is exceptional. Many of our great rivers, like the Rio Grande, Alabama, Savannah, and Cape Fear, are pooled near the sea-board within barriers of sand cast up by the waves, through which they with difficulty maintain passes with the help of the tides; others, like the Saint Lawrence, Penobscot, Kennebec, Delaware, and Susquehannah, find their way through depressions more ancient than their action; while, in the case of the Hudson, we have a stream which empties its waters through a fiord in one direction and an inlet in the other.

These considerations, and the fact that rivers, however great in volume, effect but small changes at the sea-board by reason of the superficial flow of their light waters over the more dense waters of the sea, seem to warrant our ignoring the *river-mouth* as a distinct form of harbor, and make our two grand divisions all-sufficient.

The principal points of distinction between inlets and fiords are as follows: The inlet has a depression between the chops, indicating that the waters escape under restraint, and the material missing from the depression is piled up by the sea outside as a bar. There is usually an inside bar also. The *fiord* has no depression at its mouth, and no bar outside or inside.

Both of these great classes are subject to interior obstructions from accumulations of sand and mud, and present in their sheltered portions similar characteristics; they differ usually in the amount of material supplied for shoal formations, although they often agree in their dependence upon the working-power of currents for the maintenance of their principal avenues.

The fiord in its natural state, if not the recipient of fresh-water streams, is usually slow to change along its deep-water ways. The dash of the waves may wear its shores and extend its superficial area, but little of this material finds its way into the deep water. The small depth of silt on the bottoms of our great ponds in New England illustrates the slow progress of accumulation in still water. Dead angles along shore and abrupt depressions in the bottoms of the fiords of Maine are often found to be filled up with mud and sand; and if these are not pushed out by artificial change of regimen, the more central channel-ways fill up very slowly. If strong tidal currents occur in the fiord, the channel-ways they traverse are maintained; but the flats and dead angles receive deposits in greater ratio than they would if the fiord were tideless, because the

tides not only assist in washing away the banks, but they bring in from outside material supplied by the break of the sea along the coast, and this is in excess of what is carried off by the same agencies.

The considerations to be entertained in locating harbor-lines may be arranged under the following heads:

1st. *No encroachment should be suffered that will materially reduce the tidal volume, and by this means lessen the scour of the currents that maintain the channels below.*

2d. *No encroachment should be suffered that will greatly augment the scour in the less important portions of the harbor, if the material of the bottom is yielding and likely to be swept down into more valuable parts of the port.*

3d. *Artificial structures should be carried out to a regular line so as to have a uniform or uniformly varying flow of the current along the frontage.*

4th. *No encroachments should be suffered that injuriously reduce the anchorage-basins or the winding-room near the commercial water-front.*

5th. *The harbor-line must not be so drawn as to deprive any shore-owner of his frontage.*

6th. *No riparian proprietor should be permitted to extend his wharves or lands to such a degree or in such manner as to obstruct or lengthen the pathways of vessels bound in or out from other water-fronts.*

7th. *The wharves should be carried out to water deep enough to float the class of vessels likely to visit the port for purposes of trade.*

8th. *Sufficient room should be left within the harbor-line for slips or docks of sufficient length to accommodate the longest vessel likely to demand a berth.*

9th. *The law fixing the harbor-line should be explicit regarding its location.*

Recalling what we have said in the opening clause of this paper, the above list of points to be considered will not be regarded as *rules*, and will not be supposed, as a whole, to apply in any particular case. We shall proceed to take up these propositions in detail, and discuss their application.

VALUE OF TIDAL VOLUME.

That in most of our tidal harbors the maintenance of the channels depends upon the preservation of the interior reservoirs with which they communicate is a general proposition so readily admitted by all who are conversant with the subject that we need not discuss the general case. But since the only purpose that a community can have in protecting a port against injury is to make the most of it, now and hereafter, for commercial uses, it behooves us to study the degree of harm which encroachments at any desirable point may effect, and to draw the line carefully between use and abuse.

If we compare *differ nt* harbors with each other, we discover that their navigable facilities do not vary in the ratio of their tides, whether we regard rise or volume. If, however, we compare repeated surveys of the *same* port, we find that a loss of tidal volume, by the filling up of a reservoir, has been, as a general rule, followed by a decline of *section* in the channel which formerly served as a conduit for filling and draining this basin.

The first comparison teaches that upon the *arrangement* and *relative location* of the reservoirs, as much as upon their tidal capacity, depends the existence of channels suited to our uses; while the second comparison shows that a tidal reservoir is worth preserving only in the proportion that its filling and draining tends to preserve the particular channels useful to commerce.

Compensation in kind.—It has many times been proposed by harbor-authorities to establish a law in each port that "*for all encroachments upon tide-water, restitution in kind should be made elsewhere.*" If by "elsewhere" is meant *in adjacent portions of the same basin*, this would be a safe rule of course; but if a transfer to another basin, or even to quite another part of the same basin, is within the meaning of the rule, it is a dangerous one, for it proposes to change the *order* of the tidal volumes upon which the channels, as we find them, depend. All this has been so fairly discussed in the reports of the councils and commissioners on Boston and Portland that further comment is unnecessary. Suffice it to say that with the same tidal volume not one in a hundred of the indentations upon our coast is a harbor suitable for our use, and this consideration alone

should warn us of the delicacy of any experiment which proposes to divert great forces like the tides from their natural course with the hope of making them serve equally well or better in another way.

Of course, where it has been ascertained that the tidal volume of a basin is essential to the maintenance of an important channel below, every endeavor should be made to prevent a reduction of this volume, and to this end it may be necessary to draw the harbor-line well up on the strand above low water, so that the dredging which will become necessary to convert this line into a proper commercial front will add as much tidal volume outside of the line as the occupation of the space within may displace.*

On the other hand, rather than exercise a false economy by restricting in any degree the commercial progress of a port, it is often the best and wisest policy to draw the harbor-line well out from the shore, and provide for repairing the damage that occupation out to this line may effect by charging riparian owners for the space thus granted to them, and reserving this sum to defray expenses in dredging the channel. The State of Massachusetts has adopted this policy in its treatment of the upper harbor of Boston, where the occupant of territory within the harbor-line is charged for every cubic yard of tide-water displaced a sum equal to that required for excavating the same amount. The board of harbor commissioners, nevertheless, make the explicit statement that "this compensation-fund is accumulated, not because Boston Harbor can be better preserved by dredging-machines than by maintaining the natural scour caused by the tidal reservoirs, whose action is independent of human effort and human supervisions, and costs nothing; it is accumulated to remedy the injury that is *necessarily* done in adapting a water-front to commercial uses, because this is the best that can be done to preserve the harbor, and at the same time use it."

Since it never happens, perhaps, that all the scour induced by the filling and draining of a basin is exercised to the best advantage as far as our wants are concerned, the cost of repairing the *immediate* injury done by displacement is hardly likely to exceed the cost of an equal amount of dredging, executed under the most ordinary conditions of depth and character of materials. The objections, however, to making, once for all, an assessment at a fixed rate, irrespective of the value of the territory, are obvious when it is considered that the burden falls unequally, that the repairs cannot be made *once for all*, and that money changes its value as represented in labor; and this suggests that the State would better collect a rental or tax as they do in providing for the repairs of other highways on shore.

There is one type-case to be mentioned where no indirect compensation for encroachment can avail; it is that of a lagoon, where the channel over a sandy bar, upon the outside coast, depends upon the filling and draining of this reservoir. The several attempts which our Government has made to deepen the channels over the outside bars of lagoon-inlets have been unsuccessful. "As a general rule," said the late Professor Bache, "you may as well attempt to bail out the sea as to dredge a channel through an inlet-bar."

Relations subsisting between the channels and the tides that traverse them.—The first step to be taken to determine in what manner a channel is formed or maintained by the tides is to compare velocities with depths at several cross-sections. Wherever the bed of the stream is alluvial, this comparison discovers to us, usually, that ebb and flood currents take very unequal shares in the work.

In the diagram which accompanies this paper, we have given in a sub-sketch such a comparison as that we have indicated in a characteristic case where the ebb is the principal working agent.

Where the bottom is sandy, there is, under ordinary circumstances, no suspension of the material, but the grains are *rolled* a little way by each stream, and the journey eventually made by these grains lies in the direction of and in proportion to the *resultant* of the forces precisely as if these forces were simultaneous.†

* This precaution has been taken with regard to the Charles River Basin above Boston, in the manner recommended in a report of Prof. H. L. Whiting, Seventh Report Massachusetts Board of Harbor Commissioners.

† This was first shown to be the case in our work on New York Bar. See Annual Report of the Coast Survey for 1859, Appendix 26.

In examining a case of this sort, we should take observations every fifteen minutes for a tidal day, at each of three or more stations in the cross-section, and work up the observations at each station by *composition of forces*, and then, instead of plotting maximum ebb and maximum flood as in our sketch, we should compare the transverse curve of *resultants* with the profile of section, and expect to find that it only requires a co-efficient to make the two curves agree closely.

Scour is a frictional action dependent directly upon velocity and independent of the weight of the superincumbent water. Nevertheless, since the velocity would depend upon the volume passing a given section at different stages of the tide, it will be found that a tidal channel, through alluvia, enlarges its section as it nears the sea, and this must not be lost sight of in locating harbor-lines.

If we were to construct an artificial channel leading from a deep basin to the sea, we should provide for a gradual enlargement of the channel-sections in the ratio of the tidal volumes at the stage of greatest fall—usually immediately after half-tide.

Comparisons like those we have indicated are useful in determining the relative values of different reservoirs, and also in ascertaining the probable effect of encroachments upon the width of the main channel. If the material prone to encumber the channel is sand, a very distant reservoir is often much more useful than one nearer the scene of trouble. A distant reservoir, being filled late and drained late, tends to quicken the flood-current in the channel below when the latter is nearly full, and the ebb when the channel is quite low. The flood-velocity is augmented but little, while the ebb-velocity is increased very much. Such a reservoir performs a great service, and should be preserved. Of course, a reservoir may be so distant as to send its waters down the channel after the flood-current has commenced to run in at the mouth of the harbor. In this case it would be of no use, or even injurious. Of course, as we have selected for harbors those indentations of the coast which have good channels, we rarely find in the cases brought before us, natural reservoirs that do not play some useful part in the scour of the channels below them.

One of the greatest objections to *compensation in kind* is that by expending money in enlarging reservoirs, rather than by directly deepening the main channels with the dredge, we do not get our money's worth of practical advantage. We increase the scour through the whole length of the channel when much of it is deep enough already.

ENCROACHMENTS ON THE CHANNELS.

The comparisons made between the transverse curves of velocity and the profile of the section often disclose the fact that there is a resultant, because the two streams differ in the positions of their maximum velocities, (as in our sketch.) Sometimes, in such a case, we find that two deep channels lie nearly parallel to each other with a bank between; in one channel, the resultant takes the direction of ebb; in the other, that of flood. If both streams were crowded into the same path, under such circumstances, we might have a channel much more shallow than either of those we had before, because the ebb and flood might counteract each other. We have often seen inside-bars at our southern inlets very shallow, although traversed by violent currents, because the outflow and the inflow were equal and opposite; such a bar is always in motion, but only moves to and fro.

Practically, we rarely find at a contraction an equality of ebb and flood currrents, not only because these two drifts prevail at different average heights of the tide, but also because they are differently converged or gathered in as they approach the narrow pass. But just above or below they balance each other, and shoaler water is found.

Where the bed and banks of a channel are of mud or other suspensible material, encroachments upon either side tend to deepen it, and this brings us to the question, how shall harbor-lines be drawn so as to provide, as far as possible, against disturbing the regimen of the streams. Before entering upon this question, we would repeat that we have selected our harbor from among the many indentations of the coast, because its channels are the most favorable as regards uniformity of good depth. If, then, we would maintain these advantages, we must guard against encroachments that will disturb the order of the scouring forces. The most ordinary cause of trouble in our harbors is the irregular encroachments upon the borders of the channel, which

quicken the stream at one point, and retard it at another, the effects of which are excavations at one point, and shoal-building at another.

The harbor-line, on either side of a channel, should follow as nearly as practicable the same *isodynamic curve*, a term which we introduce because it covers two kinds of scouring action, one of which is due to the simple velocity of ebb or flood, the other to the resultant of these two.

Isodynamic lines.—If the channel-bed and banks are composed of soft material, liable to be stirred up and suspended by any increase of velocity in the stream, our custom has been to draw lines of equal velocity for flood and for ebb, and in locating the *harbor-lines* make the best compromise possible between these two sets, or give the greater weight to the stream (ebb or flood) which has the greater velocity. In using the simple velocities we select the maximum flow, which occurs about the middle time of ebb or flood currents.

If the bed and banks of the channel are sandy, the resultants of the movements of ebb and flood are to be used instead of the simple velocities, because sand, as we have before stated, is prone to move in the direction of these resultants.

The difficulty in properly drawing these isodynamic lines lies in their reduction to the mean. The different transverse curves of velocity cannot be simultaneously measured, and the observations are, therefore, affected by the diurnal and half-monthly changes in the duration and magnitude of the tide. To meet this difficulty we proceed as follows:

Upon one of the lines crossing the channel at right angles to the flow, make observations enough at different points along the line, and at different depths below the surface, to ascertain the volume passing in either direction, selecting a day when the tides are about at their average, and correcting by simple proportions. If the basin to be filled, and the channel communicating with it, had vertical walls, it would be nearly correct to assume that the velocities are in proportion to the duration and height of the tide; but, as the banks are sloping irregularly, we can only make this assumption when the observed tide is very near the average.

Having carefully determined the mean volume at one cross-section, we ascertain what it would be for the next by adding or subtracting the tidal volume for the space between, which tidal volume is simply the area multiplied by the rise or fall for the unit of time for which our velocities are stated. Knowing, then, what volume should pass any section under average conditions, we correct our transverse curve by applying such a co-efficient as shall make the velocities multiplied into the depths give this standard volume.

In our sketch the transverse curves given in light, full lines, having been each of them corrected in the manner above described, represent the mean velocities in the cross-section under the same average tidal conditions. As we may not have made this matter sufficiently plain, we give below an example from one of the curves given in our sketch.

Determination of the transverse curve of velocities for section A B, at middle time of ebb, 1*h.* 43*m. after transit.*

Distance.	Distance of station occupied.	Velocities per hour. Observed.	Velocities per hour. From 1st plot.	Depth at same time.	Area of section.	Velocity of cross-section.	Velocity per hour corrected.
1	2	3	4	5	6	7	8
Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Cubic feet.*	*Feet.*
0	...	...	...	0	...	...	0
100	100	450	450	7	1,400	630,000	500
200	...	...	...	...	...	...	1,400
300	...	...	1,980	18	3,600	7,128,000	2,200
400	400	2,700	...	...	...	...	3,000
500	...	...	3,520	27	5,400	19,008,000	3,800
600	600	4,095	...	...	...	...	4,550
700	...	...	3,600	27	5,400	19,440,000	4,000
800	...	...	...	...	...	...	3,400
900	900	2,565	2,565	14	2,800	7,182,000	2,850
1,000	...	...	...	...	...	...	2,500
1,100	...	...	1,890	9	1,800	3,402,000	2,100
1,200	...	...	...	...	...	...	1,800
1,300	1,300	1,350	1,350	13	2,600	3,510,000	1,500
1,400	...	...	...	...	...	...	1,200
1,500	...	...	855	12	2,400	2,052,000	950
1,600	...	...	...	...	...	...	750
1,700	1,700	495	495	7	1,400	693,000	550
1,800	...	...	...	...	...	...	400
1,900	...	...	180	2	400	72,000	200
2,000	...	...	...	...	...	...	0
						63,117,000	

Volume previously obtained at standard section	74,220,000
Tidal volume for intermediate space	4,090,000
Standard volume for this section	70,130,000
Dividing by 63,117,000 gives co-efficient of correction for velocities	1.111

REMARKS.—The distances in the second column are those of stations simultaneously occupied, and are measured from the right bank of the stream.

The data in the fourth column are obtained from a plotting upon profile-paper of the actual velocities observed—given in the third column.

The depths given in the fifth column are from soundings corrected for the height of tide at the time when the velocities were observed.

The corrected veloctics given in the last column are obtained by applying the co-efficient (1.111) to the data given in the fourth column.

Our first attempt at determining transverse curves of velocity, with the view of ascertaining the proper limits of encroachments, was made in San Francisco in 1870; but full applications of our method were first made at New York and Portland in 1872–'73.

In the case of Portland we had a hydrographic survey of the channel and reservoir,* in which the slopes of the shore were given up to the plane of mean high water, so that, with the recorded heights of the tide before us, we could measure the volume drained or filled for every hour, and deduce the mean velocity that should obtain in each section of the channel. This process is more accurate than the one illustrated by our numerical example given above, provided the distance or extent of the reservoir is not so great as to involve large variations in the times of the tide. But under the most favorable circumstances likely to be met with in nature, the calculations for volume from the best survey of a tidal basin, are laborious and liable to errors. It must be remembered that an error in our standard volume neither affects the courses of our isodynamic lines nor their relative positions, but simply shifts the whole system a little too far out or in.

* Made by Horace Anderson, assistant, Coast Survey.

It is impossible to prescribe, in any general way, which of the isodynamic curves the harbor-line should follow, because this must depend upon the character of the bottom, &c. Suffice it to say that we consider three-tenths of a nautical mile per hour as the minimum limit of scouring velocity, and in composing the observed velocities to ascertain the resultant we reject all those which fall below this limit.

ANCHORAGE SPACE AND WINDING ROOM.

The popular rule for anchorage is, "*Run out a scope of chain equal to three times the depth.*" Accepting this rule as applicable under ordinary circumstances, we find the swing-room at anchor (making due allowance for the slant of the chain, supposed to be taut) is a circle of which the radius is the length of the vessel added to 2.82 times the depth. If we take, as an example, a schooner 100 feet long, anchored in 30 feet of water, we make her allowance of swing-room a circle of 185 feet radius, having an area of two and a half acres.

In determining the anchorage capacity of a harbor, we plot upon the chart circles of different diameters corresponding to the different classes of vessels likely to visit the port, and mingle these in proportion to the number of each class, having due regard to draught.

We may conveniently divide vessels into four categories:

First-class ships, (including ocean-steamers,) 200 to 430 feet long, with 18 to 25 feet draught.

Ordinary barks, 130 feet long, with 15 feet draught.

Ordinary brigs, 103 feet long, with 10 feet draught.

Ordinary schooners, 93 feet long, with 10 feet draught.

As regards numbers of vessels in each of these categories, returns from our principal commercial ports give the ratios 1: 2: 1½: 2½.*

Practically, vessels, under ordinary circumstances, do not swing over the whole circle we have provided, but simply over opposite quadrants; moreover, they swing together with the same wind or tide. Nevertheless, since vessels cannot be packed into an anchorage as economically as we can plot their circles upon the chart, our rule for measuring the anchorage-capacity of a basin will be found just and convenient. Take, for instance, Vineyard Haven, the most frequented refuge on our coast. Our rule gives for this port 174 miscellaneous merchant-vessels, (barks, brigs, and schooners, measuring in the average 260 tons.) The port is sometimes so full that many vessels are prevented from entering, and those at anchor injure each other; yet the largest number ever counted was 200, with an average of 200 tons each—a very large proportion being schooners. The area of the anchorage-ground beyond the 18-foot curve is 544 acres; from which we may infer that, in square measure, 2.7 acres is the best average that can serve a coasting-fleet in that roadstead.

The popular rule we have quoted above is not applicable to very large vessels, which generally require more scope. In ordinary roadsteads, of less than ten fathoms, a man-of-war requires 32 acres of swing-room; and the Spanish frigate Numancia, which lay in the lower bay of New York in the summer of 1872, cruised over a space of 44 acres; although, as it proved, her scope of chain was not sufficient to prevent her from dragging a little. We mention this vessel, because she drew more water than was ever before brought over the bar.†

In locating harbor-lines we have not only to provide against undue encroachment upon the anchorage-ground, but to take into consideration the wants of vessels under way, and those hauling in or out of the slips. If the channel has no abrupt turn in its course, steamers and vessels in tow of steam-tugs may be accommodated with a fairway of one hundred feet, but sailing-vessels require room enough to go about. Vessels vary so much in their maneuvering qualities that no close rule can be laid down for the width of a convenient sailing-channel. A first-class ship requires a half-mile of sea-room, and a medium schooner 600 feet, when beating to windward under ordinary circumstances.

To get in or out of a slip a vessel should be allowed three times her length beyond the pier-heads.

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* Computed from Lloyds.

† This may be considered a proper limiting illustration, the Great Eastern being anomalous.

REQUISITE DEPTHS OF FRONTAGE.

The Government, in removing obstructions in New York Harbor, has adopted 25 feet at mean low water as the maximum depth required, and in Boston 23 feet. The former gives 27 feet from the mean level of the sea, the latter 28 feet.

Of the sailing-ships registered at Lloyds, only one-third draw over 20 feet, while 95 per cent. draw over 16 feet. Of the barks only 3 per cent. draw over 20 feet, and 27 per cent. over 16 feet. Of the brigs only 3 per cent. draw over 16 feet. Coastwise coal-loaded steamers usually draw 15 feet, and coal-loaded schooners 12 feet; the average draught of merchant-schooners is, however, only 10 feet, and fishing-vessels less.

The contours of the natural frontage, where the bed and bank of the stream are of yielding material, will usually be found parallel to the isodynamic lines commented upon above, but not necessarily so to the *direction* of the current.

REQUISITE LENGTH OF SLIPS, ETC.

We have already spoken of the lengths of vessels, but not of their widths. In the following table we give these and other details.

Dimensions of vessels, (mostly from Lloyd's Register.)

Vessels.	Tonnage.	Length.	Beam.	Draught.	Remarks.
		Feet.	*Feet.*	*Feet.*	
Large ocean-steamers	4,000	430	42	24	Avoiding extreme cases.
Large sailing-ships	1,700	210	41	22	16 per cent. of such ships draw 24 feet and over.
Ordinary ships	1,000	178	35	20	
Small ships	400	140	27	16	
Sound steamers	3,000	373	83	12	"Bristol" and "Providence," (beam over all.)
Large coastwise coal-steamers	1,500	200	37	15	Reading Railroad Company.
Large barks	950	164	36	19	Avoiding extreme cases.
Small barks		102	23	11¼	Do.
Large brigs	450	125	29	15	Do.
Ordinary brigs		102	25	12	
Large schooners	400	130	30	13	Avoiding extreme cases.
Ordinary schooners	133	93	24	10	
Special coal-schooners		130	30	12	Reading Railroad Company.
Stone-sloops			26	9	Pigeon Cove Granite Company.

In the foregoing table no projections beyond the hulls of the vessels are counted.

In order to furnish fair berths for two ships, the water-space between wharves should be about 100 feet wide, 250 feet long, and 20 feet deep as far up the slip as the ships' keels extend. These dimensions cover all necessary projections of head-gear, &c.; they also admit of the two ships being replaced by four ordinary schooners, leaving ample space for passage-way between those on opposite sides.

Although the water-fronts in most of our ports are now occupied only by wharves, there are places where continuous quays would be much more economical, and other places where docks with open gateways would be safer and more convenient. In great estuaries, like Delaware Bay, where the alluvia along shore is liable to shift, and is prone to do so immediately after the erection of projections at right angles to the flow, a continuous quay, protected by ice-breakers, is the best and most permanently useful improvement of the water-front. Our harbor-lines usually indicate simply the outer limits of pile or crib piers extending from the shore.

Riparian rights.—Under the general principal that *each shore-owner has a right of way out to sea from every part of his frontage*, it would seem just that when he chooses to extend his wharf to the harbor-line he should be entitled to his proportional share of said line. Where the harbor-line is parallel to the shore, his proportion is secured by extending the side-lines of his lot in directions normal to said harbor-line; but in the case where his estate lies upon the shores of a shallow cove, within which it is inexpedient to draw a harbor-line parallel to the shore, a special method of division must be resorted to, in order to secure to each riparian owner his due proportion of the harbor-line adopted.

Before referring to the methods of division heretofore adopted or proposed, we shall offer a rule, which seems to us of very general application.

Having plotted the harbor-line, which may either pass wholly outside of the mouth of the cove or bend into it, draw a sweeping-line through three or more salient points in the high-water margin of the cove in such manner as to present towards the harbor a divergent curve, and extend the side lines of the riparian estates out to this line of rectification in directions normal to said line. Then (premising that the harbor-line has been parceled out to the owners above and below the cove) divide the unallotted portion of the line in front of the cove into parts proportional to the divisions of the line of rectification already referred to, and extend the estates by straight lines to embrace these parts.

One may easily see that if the harbor-line is drawn with no reference to the *form* of the cove, cases may arise where an application of this rule would be inequitable; but since the main purpose of the harbor-line is usually to secure to each his due share of the frontage, no such difficulty may be expected to arise. Where a harbor-improvement, beneficial to the many and detrimental to the few, is contemplated, the location of the harbor-line may be made regardless of the interest of some individuals, but in such cases the injured should be made whole from the "betterments" elsewhere.

The rule we have given is based upon certain decisions of the court in Massachusetts, and its slight departure from the actual usage will be appreciated by the following very interesting discussion, which we quote from Allen's Report of Cases Argued and Determined in the Supreme Judicial Court of Massachusetts, volume XIX. The court appointed commissioners to divide the flats of a cove in Gloucester, and this commission seemed to have assumed that this division was to be in *proportional areas*.

"No rule, to our knowledge, having been established for the division of flats in a cove of this description, out of which the tide never entirely ebbs, nor any rule of division in any case adopted which is capable of a general application to shores of different shapes, it was suggested to us that the mode heretofore adopted in some cases, claimed to be analogous to the present, of deep coves, out of which the tide entirely ebbs, to wit, by drawing a line across the mouth of the cove between the headlands, and giving to each shore-owner his proportionate length of flats on that line, should be followed in this. But we were of opinion that this mode was not properly to be applied to this case, or to cases of coves from which the tide does not wholly ebb at the lowest tide, inasmuch as the base-line upon which the division would be made must pass outside of the limits of the ownership of the parties, and where no actual measurements or monuments could be had. * * * * * * * * * * *

"And we have adopted the following mode of division as one fair and proper in this case, to wit, we fix the boundaries by division-lines drawn through a series of points or lines between the established limits of the cove, equidistant from the line of high water, which points are found by dividing said equidistant lines in the ratio as the lengths of the lines of upland owned by the parties on said high-water line, giving to each shore-owner his proportionate share of the area of each belt of flats thus formed around the cove, until the limit of his ownership in the direction of low water is reached, the said belts as represented upon the plan being ten feet in width; the division-lines so ascertained being represented upon the plan by the irregular and curved lines from the bound marks on high-water line to low-water line," (and marked, on the plan, ante, 73, a 1, b 1, c 1.) "It was objected to this mode that it gives division-lines of boundary, curved and irregular, and not adapted to the construction of wharves upon the premises.

"But we have considered that the use for construction of wharves is not the sole purpose for which the premises are valuable, nor the purpose for which such property is always of the most value, and that by law the right of occupation of flats adjoining the upland is not co-extensive with the ownership, since it cannot stop or hinder the passage of boats or vessels to other men's houses or lands; and further, that the courses of these lines will not be more irregular than the shore-lines upon which they depend, nor than the line of low water, nor than natural lines of boundary generally; and that they mark a division fair and proper in the premises, which gives to each owner his due proportion; and that the rule by which they are run is capable of a general application to coves of all shapes, and to headlands and shores of the open sea as well, giving to the shore-owners in all cases their proportionate shares of the area of the adjoining flats, marked by boundary-lines in the direction of low water upon the courses indicated by nature in the formation of the shore. * * * * * * * * * * * *

"The petitioners objected to judgment upon the report of the commissioners for the following reasons: 1st. That the division reported by the commissioners is not the true and legal method for dividing the flats in said cove and determining the boundary-lines of said petitioners. 2d. That the true method of division is in the ratio of the length of ownership of the petitioners respectively on high-water line, upon the line of lowest low water between the established limits of the cove as determined in said report, or upon the tangent-line between headland and headland, as these two methods of division are indicated upon the plans returned by said commissioners. 3d. That said commissioners should have divided the flats in said cove, and determined the boundaries of the petitioners by setting off to the petitioners the flats appurtenant to their upland respectively, without reference to any wharves or structures upon the same. * * * * * * * * * * * * * * *

"The court is clearly of opinion that the mode preferred and selected by the commissioners is erroneous. It is novel and unprecedented, utterly different from and inconsistent with any of the principles and rules which have been laid down or suggested in the adjudged cases, and evinces more scientific ingenuity than practical wisdom. It is artificial and complicated, requiring much mathematical skill, minute surveys, and elaborate calculations, to apply it to particular cases. It does not give to each proprietor a width on his outer line either equal or proportional to that which he has at high-water mark. It determines the width of each parcel of flats, and the direction of the side-lines thereof, neither by the natural line of low-water mark, nor by a base-line drawn between the natural monuments at the headlands of the cove, nor by the outer line of proprietorship; but by a series of arbitrary lines, many of which fall partly within and partly without the flats to be divided, and which in the deepest parts of this cove lose even the apparent consistency and approximation to a series of parallels with which they begin at high-water mark. The dividing-lines do not run in the straightest and most direct course to any points on low-water mark, or the seaward limit of proprietorship; but are curved and serpentine, making each lot of a shape peculiarly inconvenient for the building and use of wharves, while the flats continue to be appropriated to the purposes of commerce and navigation, and equally difficult of sale or improvement after the flats shall have been filled up."

LAWS ESTABLISHING HARBOR-LINES.

The legislative act establishing a harbor-line usually takes the form of a prohibition, thus: "No wharf, pier, or other structure in the harbor of ——— shall ever hereafter be extended into and over the tide-water of said harbor, beyond the line hereinafter described."*

In nearly all cases that have come before us for revision, there have been found serious faults in the description of the lines, especially as regards the deflecting-points whose exact positions are not carefully fixed, as they should be, by stated courses and distances from known and permanent objects. What we mean by known and permanent objects may be seen in the following quotation from a description of proposed harbor-lines recently drawn up by the Coast Survey at the request of the harbor commission of New Castle, Del.: "The quay-line, beginning at a point in the center-line of North street extended 790 feet seaward from the *initial stone* at the intersection of the center-lines of Market and North streets, runs southwesterly in a straight line to a point in the center-line of Chestnut street extended 882 feet from the *initial stone* at the intersection of the center-lines of Chestnut and Market streets; thence southwesterly in a straight line to the east corner of the *rectangular ice-pier* off Truss's wharf; thence along the outer face of said pier to the south corner of the same; thence southwesterly in a straight line to a point in the extended line of the west side of the *old ice-pier* (forming now a part of Holmes's wharf) 57½ feet from the south corner of said pier; thence westerly in a straight line to a point in the center-line of Delaware street extended 464 feet from the *initial stone* at the intersection of the center-lines of Delaware and Front streets; thence in a straight line to a point in the center-line of South street extended 1,002 feet from the *initial stone* at the intersection of the center-lines of Pearl and South streets; thence westerly in a straight line to a point in the center-line of Johnson street extended 846 feet from the *initial stone* at the intersection of the center-lines of Johnson and South streets."

The above is, perhaps, as simple a case as could well be found, but the description might be improved by stating the true course of each line. It is customary to refer to light-houses, churches, and other public buildings, and to corners of street-blocks where no initial stones exist. It has also been customary to refer to corners of wharves, but this is not advisable unless the wharves are of stone already extending to the line.

Harbor-lines when fixed by the legislature are intended to be permanent, but the same authority can change them, and few old cases that have come to our knowledge have escaped some change. Therefore, when a scheme of lines is presented to the legislature, it should be accompanied by a detailed report setting forth the reasons for the location of each section, in order that, if at any future time the exigencies of commerce may seem to demand some changes, all the original augments may be duly considered. Most of the old harbor-lines rest only upon the authority of the names of the experts who made up the commissions recommending them. In our own experience we have never made up a scheme of lines in which the different sections were equally well based, and in some cases we have felt obliged to state that this section or that was entirely arbitrary, and simply introduced as a connecting-link in the chain.

The foregoing is, as far as we know, the first attempt at a general essay upon harbor-lines, and this must be our apology for its faults.

Submitted to Prof. Benjamin Peirce, Superintendent of the Coast Survey, November, 1873.

* First section of the act entitled "An act to establish harbor-lines in Cape Cod Harbor in Provincetown," passed by the general court of Massachusetts in the year 1867.

APPENDIX No. 11.

COMPARISON OF THE METHODS OF DETERMINING HEIGHTS BY MEANS OF LEVELING, VERTICAL ANGLES AND BAROMETRIC MEASURES, FROM OBSERVATIONS AT BODEGA HEAD AND ROSS MOUNTAIN, CAL., BY GEORGE DAVIDSON AND CHARLES A. SCHOTT, ASSISTANTS, UNITED STATES COAST SURVEY.

In the spring of 1860, Assistant George Davidson organized a system of observations of heights with a view of determining the refraction of the atmosphere in the climate of California, and to give data for relative values of heights determined from leveling operations, from measures of zenith-distances, and from readings of the atmospheric pressure. The stations selected were Bodega Head, on the sea-coast, about fifty statute-miles northwesterly of San Francisco, and Ross Mountain, about fourteen miles to the northward of Bodega Head. The "head" is about 240 feet and the "mountain" about 2210 feet above the level of the ocean. Starting from Bodega Head, the line passes for about one-third of its length close to the coast-line, and at two-thirds it crosses the deep valley of the Russian River. Local currents of the atmosphere, due to this valley, may possibly cause disturbances in the normal refraction.

The two stations were occupied in March, 1860, and between the 20th and 27th hourly observations (from 7 a. m. to 5 p. m.) were made of reciprocal and simultaneous zenith-distances, and of the pressure, temperature, and moisture of the atmosphere.

The height of Bodega Head was determined by leveling in August, 1860, but it was not till 1872 that an opportunity offered for carrying the levels up to Ross Mountain. The results of this paper will be given under the three divisions of the subject stated in the title.

1.—THE RESULTS OF THE LEVELING OPERATIONS.

These operations being well understood, and presenting nothing new or of special interest, the following brief statement will suffice:

The elevation of Bodega Head was determined by spirit-level, by Assistant George Davidson, August 20, 1860. The staff could be read by means of a vernier to 0.001 of a foot. He found—

Bodega Head mark above bench-mark near tidal station	234.6 feet.
Reduction to ground, or top of copper bolt....................	− 0.1
Reduction to half-tide level of ocean	+ 6.6
Hence, Bodega Head, ground, above ocean..................	241.1 feet = $73^{m}.49$

By direction of Assistant Davidson the elevation of Ross Mountain was obtained by spirit-level in January, February, and March, 1872, by Mr. S. R. Throgmorton, aid, United States Coast Survey, assisted by Mr. H. J. Willey. The levelings commenced at Bodega Head, and received a rough check by striking high-water mark at Salmon Creek; from here the line of level crosses a ridge of about 250 feet, and descends again at the Russian River to tide-water level; the ascent of Ross Mountain was retarded by wet and windy weather, and in returning the work had to be abandoned after descending about 1,350 feet, on account of the wet and spongy ground. The check-levels during the descent were satisfactory. The leveling-instrument, by Stackpole & Bro., of New York, was borrowed from General Alexander, United States Engineers. The rod was compared with the standard steel-yard, at 62° Fahrenheit, and the extreme length and intermediate graduation were found to agree with the standard.

The resulting difference of level is as follows:

	Feet.
Ross Mountain, stone mark above ground, Bodega Head	1963.55
Reduction of mark to ground at Ross Mountain	+ 0.85
Ross Mountain, ground, above Bodega Head	1964.40
And by preceding result, Bodega Head, ground, above half-tide level of ocean	241.10

Hence, Ross Mountain, ground, above half tide of ocean .... 2205.50 feet, or 672.23 metres, and the difference of height of the ground at each station 598.74 metres, with an estimated probable error of $\pm$ $0^{m}.06$

2.—RESULTS OF HOURLY OBSERVATIONS OF RECIPROCAL AND SIMULTANEOUS ZENITH-DISTANCES FOR DIFFERENCE OF HEIGHT OF THE TWO STATIONS.

The observations at Bodega Head, between March 20 and March 27, 1860, were made by E. H. Fauntleroy, aid, United States Coast Survey. He used the 10-inch vertical circle No. 80; it is graduated to 5′, and reads by 4 verniers to 3″ each. Its optical power was rather weak for the work required. One division of the level equals 5″.53, as determined by Assistant Davidson in 1859. The axis of the vertical circle was 62.5 inches (1.587 metres) above ground, and the elevation of the heliotrope shown to Ross Mountain was the same. The zenith-distances of the Ross Mountain heliotrope were measured on five days at every full hour, (excepting one on the first day,) between 7 a. m. and 5 p. m. inclusive. Each measure consists of six repetitions of the double zenith-distance, and was corrected for defect of verticality of axis as indicated by the level. Immediately before and after each measure the barometer, with attached thermometer, and the dry and wet bulb thermometers, were read, and the state of the weather noted generally, including direction and velocity of wind. The cistern of the mercurial barometer, Green No. 1343, was 0.336 metre above ground. Its index-correction, when compared with Green's mercurial barometer No. 1347, which was stated to be correct, was —0.010 inch, which correction was applied to the tabular results, as well as the graduation-corrections of the thermometers, No. 16, used as dry and wet bulb, and of No. 3, used as dry bulb, after the accidental breakage of wet bulb No. 16. These corrections are given further on.

The observations at Ross Mountain, between March 20 and March 27, 1860, were made by Assistant George Davidson. He used the 10-inch Gambey vertical circle No. 28; it is graduated to 5′, and reads by 4 verniers to 3″ each. Its optical power was considered weak. One division of the level equals 6″.29, as determined by Assistant Davidson. The axis of the vertical circle was 61 inches (1.549 metre) above the ground; the heliotrope shown to Bodega Head was on a level with the vertical circle. Double zenith-distances of the Bodega Head heliotrope were measured hourly, between 7 a. m. and 5 p. m. inclusive, on five days, and at four morning-hours on the 6th day, when the observations had to be discontinued on account of wet and stormy weather. The measurement of the six repetitions of the double zenith-distance was commenced exactly at the full hour, and the average time occupied in making them was about five minutes. The level was read twice before and twice after reversal of the circle, and the results were corrected for defect in verticality of axis. The barometer and attached thermometer and the dry and wet bulb thermometers were observed as at Bodega Head; the state of the weather was carefully noted every hour. The cistern of mercurial barometer, Green No. 1347, which was borrowed from Lieut. R. S. Williamson, United States Topographical Engineers, was 0.378 metre above ground. The instrument is of the Smithsonian pattern. The thermometers were, No. 8, dry bulb, No. 13, wet bulb, and the comparisons by McAllister & Bros. with a standard, and again by Assistant Davidson, gave the following index-corrections to the thermometers used at the two stations:

	°
To No. 8	0.0
To No. 13	+0.6
To No. 16, dry	+0.9
To No. 16, wet	+1.2
To No. 3	+1.1

All the thermometers have Fahrenheit's scale.

TABLE 1.—*Resulting zenith-distances, measured at Bodega Head, of the heliotrope at Ross Mountain March*, 1860.

88° 33′ +

Hour of day.	20th.	21st.	24th.	25th.	26th.	27th.	Resulting mean from five days.*
	″	″	″	″	″	″	″
7 a. m.	(*)	7.8	22.9	8.0	6.5	....	12.1
8 a. m.	28.4	14.9	20.4	6.6	16.2	31.5	17.3
9 a. m.	†[55.3]	29.5	38.1	[25.6]	18.9	33.3	29.4
10 a. m.	†[11.9]	31.7	[45.2]	23.9	17.7	39.6	[30.4]
11 a. m.	23.3	33.8	31.7	19.1	[20.3]	....	25.6
Noon	24.9	[37.7]	35.4	15.8	12.7	....	25.3
1 p. m.	30.9	25.3	28.6	11.5	15.9	....	22.4
2 p. m.	15.3	33.2	32.4	20.9	14.9	....	23.3
3 p. m.	22.4	25.8	27.3	18.9	14.2	....	21.7
4 p. m.	24.6	29.6	20.0	16.5	14.9	....	21.1
5 p. m.	25.3	24.6	11.0	− 9.2	10.5	....	12.4
Resulting daily mean	25.3	26.7	28.5	14.3	14.8	....	21.9

The last column contains the hourly means from five days of observations, rejecting the values of the 27th, as a broken day. The maximum value on each day is indicated by an inclosure in brackets.

The probable error of any one mean zenith-distance, from five days of observation, is about ± 2″.1.

TABLE 2.—*Resulting zenith-distances, measured at Ross Mountain, of the heliotrope at Bodega Head, March*, 1860.

91° 35′ +

Hour of day.	20th.	21st.	24th.	25th.	26th.	27th.	Resulting mean from five days.
	″	″	″	″	″	″	° ′ ″
7 a. m.	44.9	68.4	87.3	79.4	69.9	82.0	91 36 10.0
8 a. m.	58.5	85.9	91.2	81.8	68.3	90.2	17.1
9 a. m.	79.4	90.2	93.5	86.2	81.3	95.3	26.1
10 a. m.	84.9	87.6	[98.4]	[87.5]	77.1	96.1	27.1
11 a. m.	81.0	90.2	96.8	84.1	[87.2]	....	[27.9]
Noon	[89.7]	88.9	92.0	77.6	83.2	....	26.3
1 p. m.	87.6	[90.6]	94.4	77.2	77.3	....	25.4
2 p. m.	82.6	89.4	89.8	77.9	66.2	....	21.2
3 p. m.	87.7	82.4	93.0	78.5	73.9	....	23.1
4 p. m.	89.4	86.1	90.7	82.4	79.4	....	25.6
5 p. m.	86.7	80.6	89.2	80.5	69.4	....	21.3
Resulting daily mean	91 36 19.3	25.5	32.4	21.2	15.7	....	22.8

The observations on the 27th are omitted from the mean. The daily maxima are indicated by brackets. It will be noticed that these *maxima* of measured *zenith-distances* all occur in the forenoon, and that they appear to connect themselves with the time of the daily *maxima* of the *atmospheric pressure*, (for which see tables further on.) The average hour is near 10 a. m. This may possibly be quite local, and may be connected with the setting in of the sea-breeze about that time—a phenomenon which renders the daily fluctuation of temperature at San Francisco so different from the ordinary occurrence. The Bodega Head station seems to be slightly more exposed to this influence, as might be conjectured from its position close to the sea-coast.

* To complete the table, the value 15″.5 was here interpolated; it was found by comparing the observed zenith distance at 7 a. m. on each day with the *mean* of the 10 observed zenith-distances of the day respectively. This difference is 10″.7, which, subtracted from 26″.2, or the mean of the 10 observations on the 20th, gives 15″.5.

† Measures unreliable owing to high wind; the mean, or 33″.6, will hereafter be substituted in the place of these measures.

The probable error of any one mean zenith-distance from five days of observation is about $\pm 1''.9$.

The heliotrope and instrument being $0^m.038$ higher above ground at Bodega Head than at Ross Mountain, the angle $0''.3$ subtended by this difference will be *subtractive* to the resulting tabular zenith-distances at Bodega Head and *additive* to those at Ross Mountain, in order that the computed differences of altitude may at once refer to the ground at each station.

TABLE 3.—*Resulting atmospheric pressures observed at Bodega Head, the height of the mercurial column being corrected for index-error and its temperature reduced to that of freezing water.*

MARCH, 1860.

Hour of day.	20th.	21st.	24th.	25th.	26th.	27th.	Resulting mean from 5 days.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
7 a. m.	(*)	29.715	30.038	29.920	29.817	....	29.833
8 a. m.	29.689	.715	.038	[.930]	.827	29.765	.840
9 a. m.	.731	.734	.042	.922	[.832]	.779	.852
10 a. m.	[.749]	[.739]	[.049]	.923	[.832]	.780	[.858]
11 a. m.	[.749]	.732	.048	.925	.825	....	.856
Noon	.744	.722	.040	.913	.809	....	.846
1 p. m.	.739	.713	.018	.897	.791	....	.832
2 p. m.	.741	.702	30.000	.878	.774	....	.819
3 p. m.	.733	.679	29.987	.871	.761	....	.806
4 p. m.	.733	.668	.965	.860	.747	....	.795
5 p. m.	.730	.659	.959	.837	.732	....	.783
Mean	29.728	29.707	30.017	29.898	29.795	....	29.829

* Interpolated value for this hour 29.674 inches, using the observed difference at 7 and 8 at Ross Mountain.

Inclosed values indicate the daily maxima of pressure.

The readings on the 27th are not used in the means. The surface of the mercury in the cistern, in contact with the index-point, was $0^m.336$ above ground; hence, to reduce the observed pressure to the ground, 0.001 inch is to be added.

TABLE 4.—*Resulting atmospheric pressures observed at Ross Mountain, the height of the mercurial column being referred to the temperature of freezing water.*

MARCH, 1860.

Hour of day.	20th.	21st.	24th.	25th.	26th.	27th.	Resulting mean from 5 days.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
7 a. m.	27.618	27.617	27.930	27.844	27.737	27.676	27.749
8 a. m.	.633	.624	.934	.846	.745	.691	.756
9 a. m.	.647	.635	.942	.848	.754	.699	.765
10 a. m.	.651	.636	.948	[.869]	[.758]	.713	[.772]
11 a. m.	[.656]	[.642]	[.949]	.852	.754	....	.771
Noon	.650	.638	.947	.840	.744	....	.764
1 p. m.	.645	.621	.931	.821	.732	....	.750
2 p. m.	.637	.602	.919	.803	.721	....	.736
3 p. m.	.630	.597	.898	.793	.701	....	.724
4 p. m.	.626	.576	.884	.782	.693	....	.712
5 p. m.	.622	.572	.877	.775	.678	....	.705
Mean	27.638	27.615	27.924	27.825	27.729	....	27.746

The readings on the 27th are not used in the means.

To reduce the observed pressure to what it would have been on the ground, add 0.001 inch.

The next following tables contain the observed temperatures of the air and of evaporation; all the readings were corrected for index-errors of thermometers. The readings on the 27th are omitted, maxima are indicated by brackets.

TABLE 5.—*Observed temperature of the air and of evaporation at Bodega Head, March, 1860.*

Hour.	20th.		21st.		24th.		25th.		26th.		Mean of five days.	
	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.
	°	°	°	°	°	°	°	°	°	°	°	°
7	*48.0	*46.1	43.4	42.8	46.7	45.6	48.4	46.8	49.5	48.5	47.2 F.	46.0 F
8	49.4	46.7	50.0	46.0	48.4	47.0	52.9	49.3	50.9	49.5	50.3	47.7
9	50.5	47.3	52.3	47.2	53.1	49.8	55.9	51.2	52.3	50.6	52.8	49.2
10	50.8	47.9	55.4	49.7	58.5	53.2	[57.9]	53.0	53.5	51.0	55.2	51.0
11	50.8	47.9	[57.9]	51.0	59.4	52.4	56.1	51.5	54.8	51.7	55.8	50.9
Noon	50.6	46.8	57.0	50.5	60.5	53.3	55.9	51.3	56.1	53.8	56.0	51.1
1	[50.9]	47.3	57.5	50.7	[60.7]	54.5	55.2	51.5	56.9	54.2	[56.2]	51.6
2	50.0	46.5	53.5	48.4	58.9	54.2	55.5	53.1	[58.4]	†56.4	55.3	51.7
3	49.9	46.5	52.4	48.3	58.3	53.8	53.9	51.9	56.5	55.1	54.2	51.1
4	49.1	46.0	51.6	47.7	57.9	53.7	53.0	51.5	55.9	54.3	53.5	50.6
5	48.7	45.7	50.1	47.7	56.5	52.3	52.6	51.1	55.5	54.1	52.7	50.2
Mean	49.9	46.8	52.8	48.2	56.3	51.7	54.3	51.1	54.6	52.7	53.56	50.10

* These two values are interpolated. † This value is interpolated.

TABLE 6.—*Observed temperatures of the air and of evaporation at Ross Mountain, March, 1860.*

Hour.	20th.		21st.		24th.		25th.		26th.		Mean of five days.	
	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.
	°	°	°	°	°	°	°	°	°	°	°	°
7	46.0	35.3	44.0	36.7	40.5	38.8	47.4	43.4	49.6	43.2	45.5 F.	39.5 F.
8	45.0	36.6	43.6	36.6	43.1	40.2	48.7	43.6	51.6	44.7	46.4	40.3
9	48.5	39.7	45.3	38.7	45.1	41.6	54.4	48.6	56.5	50.2	50.0	43.8
10	49.7	42.2	47.7	41.1	48.2	43.0	55.2	47.8	57.5	49.5	51.7	44.7
11	51.3	44.9	49.3	42.7	51.0	45.6	56.5	50.6	60.0	52.5	53.6	47.3
Noon	[52.2]	44.8	50.7	42.5	53.7	48.5	57.0	50.8	62.6	54.8	55.2	48.3
1	52.1	43.6	[52.0]	43.3	[56.9]	50.3	57.3	50.5	[63.4]	55.6	[56.3]	48.7
2	51.9	43.1	49.5	42.3	55.4	49.6	57.2	48.9	61.8	53.7	55.2	47.5
3	51.0	44.2	50.7	42.9	54.2	48.0	[58.4]	52.1	59.9	52.8	54.8	48.0
4	47.7	42.7	46.9	40.4	52.8	47.1	[58.4]	52.1	59.2	52.3	53.0	46.9
5	43.3	40.0	45.0	38.1	50.0	45.1	54.5	48.9	57.8	47.7	50.1	44.0
Mean	49.0	41.6	47.7	40.5	50.1	45.3	55.0	48.8	58.2	50.6	51.98	45.36

Collecting our preceding mean results, we have the following data for computation:

March 20, 21, 24, 25, 26, 1860.

Hour of day.	Observed zenith distance at—		Atmospheric pressure at—		Atmospheric temperature at—		Temperature of evaporation at—	
	Bodega Head.	Ross Mountain.	Bodega Head.	Ross Mountain.	Bodega Head.	Ross Mountain.	Bodega Head.	Ross Mountain
	° ′ ″	° ′ ″	*Inches.*	*Inches.*	°	°	°	°
7 a. m.	88 33 11.8	91 36 10.3	29.834	27.750	47.2 F.	45.5 F.	46.0 F.	39.5 F.
8 a. m.	17.0	17.4	.841	.757	50.3	46.4	47.7	40.3
9 a. m.	29.1	26.4	.853	.766	52.8	50.0	49.2	43.8
10 a. m.	30.1	27.4	.859	.773	55.2	51.7	51.0	44.7
11 a. m.	25.3	28.2	.857	.772	55.8	53.6	50.9	47.3
Noon	25.0	26.6	.847	.765	56.0	55.2	51.1	48.3
1 p. m.	22.1	25.7	.833	.751	56.2	56.3	51.6	48.7
2 p. m.	23.0	21.5	.820	.737	55.3	55.2	51.7	47.5
3 p. m.	21.4	23.4	.807	.725	54.2	54.8	51.1	48.0
4 p. m.	20.8	25.9	.796	.713	53.5	53.0	50.6	46.9
5 p. m.	12.1	21.6	.784	.706	52.7	50.1	50.2	44.0
Mean	88 33 21.6	91 36 23.1	29.830	27.747	53.56	51.98	50.10	45.36

Notes respecting state of the weather at the two stations:

MARCH 20, 1860.

Bodega Head.—At 7^h wind strong, WNW.; atmosphere hazy. At 11^h wind blowing a gale.

Ross Mountain.—At 7^h moderately clear, sky 0.3 covered with cirrus and cirro-stratus; wind moderate, NNW.; fog to seaward and in Russian River. At 8^h fog disappeared in Russian River Valley. At 10^h fog forming along the coast south of Bodega; appears to blow fresh on the water. At 11^h wind north, light, weather getting a little thick. At noon, somewhat clearer. At 1^h wind moderately strong, NNW. At 3^h atmosphere very hazy. At 5^h wind moderately strong, N.

MARCH 21, 1860.

Bodega Head.—At 7^h weather clear, wind light, E. At 11^h wind light, SE. At 2^h wind fresh, SW. At 3^h horse tail clouds. At 5^h thick clouds overhead.

Ross Mountain.—At 7^h weather clear, calm. At 9^h wind very light, WSW., cirro-stratus to northward. At 11^h wind light, S. by W. At 1^h light wind, SSW. At 4^h sky 0.9 covered, threatening to the northwestward, wind SSW. increasing. At 5^h wind S., light. At 5^h 15^m parhelia formed, showing three-fourths of a circle, lower part not visible; two very bright prismatic images of the sun, and a faint one at vertex.

MARCH 22 AND 23, 1860.

Weather quite stormy. At 8 a. m., on the 22d, most severe squalls of wind, with rain, from the SSW. On the 23d occasional squalls; wind SSW.

MARCH 24, 1860.

Bodega Head.—At 7^h clear; wind light, SSE.. At noon wind light, SW.; atmosphere clear.

Ross Mountain.—At 7^h clear, wind very light, ESE.; snow on all the mountains eastward. At 8^h wind light, E. by N. At 9^h wind light, ESE. At noon sky half covered with cumulus, wind light, S. At 1^h wind light, WSW., and S. for the rest of the day.

MARCH 25, 1860.

Bodega Head.—At 7^h weather clear; wind very light from E. At 10^h wind light, SW. At noon fresh from W. At 2^h fog forming rapidly in line to Ross Mountain At 3^h heliotrope seen over the line of fog; scud flying over station.

Ross Mountain.—At 7^h clear, wind S., light; sky 0. At 1^h wind light, SW. At 2^h fog forming rapidly over water, and coming in. At 3^h fog just inside our line, heliotrope seen over edge of fog-cloud. At 4^h and 5^h wind light, W. and NW.; clear.

MARCH 26, 1860.

Bodega Head.—At 7^h clear, light wind, WNW.; atmosphere hazy. At 3^h wind fresh from SW.

Ross Mountain.—At 7^h clear, wind moderate, N.; atmosphere hazy to S.. At 9^h wind very light, SW.; haze on line of sight. At 10^h almost calm, clear. At noon wind very light, ENE. 1^h to 3^h wind light, S. 4^h to 5^h wind very light, SSW.; clear.

MARCH 27, 1860.

Weather cloudy, sky covered with cirro-stratus and cumulo-stratus; valleys covered with fog. Wind light ESE., between 7^h and 10^h. After 10^h rain in NW., working toward SE.; wet and stormy, with heavy gales from SE. round to SW. For the six succeeding days the fall of rain was registered 9½ inches.

The direction of wind given in the above notes refers to the true meridian. These notes are extracts from the more copious record.

The geographical positions of the stations are as follows:

Bodega Head.—Geodetic latitude, 38° 18′ 18″.7; longitude, 123° 3′ 49″.2 west of Greenwich.

Ross Mountain.—Astronomical latitude, 38° 30′ 10″.0; longitude, 123° 7′ 13″.1 west of Greenwich.

Geodetic distance of stations 22482.2 metres, and azimuth of line from Bodega Head 167° 18′

35″, and reverse azimuth from Ross Mountain 347° 16′ 29″, counted from the south point around by west.

We have also the radius of curvature,* to the earth's surface, in latitude φ and in azimuth α

$$=\frac{a\,(1-e^2)}{(1-e^2+e^2\cos^2\varphi\cos^2\alpha)\,(1-e^2\sin^2\varphi)^{\frac{1}{2}}}$$

where—

$$e^2=\frac{a^2-b^2}{a^2}$$

and the semi-axes, according to Clarke,

$$a=6\,378\,206 \text{ metres};$$
$$b=6\,356\,584 \text{ metres};$$

hence—

radius of curvature to our line = 6 361 215 metres.

Reduction of observations of zenith-distances.—For reducing these observations we shall make use of Dr. Bauernfeind's investigations, as presented in Nos. 1478–1480 and in Nos. 1587–1590 of the Astronomische Nachrichten, (1866.) These developments are preferred to others on account of completeness, and for the reason that the simple fundamental assumptions made respecting the physical constitution of the atmosphere apparently lead to results in tolerably close conformity with experience.

Terrestrial refraction between any two stations is conceived as the difference of the astronomical refractions of a ray of light passing between them, and the equation to the refracted ray is determined with consideration of the particular circumstances of atmospheric pressure and temperature, as noted at the intersecting stations.

Let—

$\alpha_0=0.00027895$, a mean value for constant of refraction, at

$\beta_0=29.6$ inches ($751^{\text{mm}}.83$) of atmospheric pressure, and

$\theta_0=507^\circ.7$ Fahr., counted from the absolute zero;

$\beta=$ observed atmospheric pressure, the mercurial column being at the temperature of freezing water;

$\theta=$ observed temperature $=459^\circ+\tau$, where τ must be expressed in degrees of Fahrenheit's scale;

$\alpha=\frac{\theta_0\,\beta}{\theta\,\beta_0}\,\alpha_0=\frac{[7.67983]\,\beta}{459+\tau}$ the rectangular brackets, including a logarithm and β to be expressed in inches;†

$r_0=$ the radius of curvature to the earth's surface in the latitude of the middle point of the arc joining the stations and in the azimuth of the line;

$m_0=$ a second constant (for a given latitude and elevation) depending on the refraction, and $=0.007464$ for the latitude of Königsberg; its values for various latitudes are given in the following table:

Lat.	m_0	log m_0	Lat.	m_0	log m_0	Lat.	m_0	log m_0
°			°			°		
0	0.008300	7.91907	41	0.007740	7.88875	51	0.007547	7.87782
10	8253	.91666	42	719	8756	52	528	7668
20	8135	.91040	43	697	8632	53	510	7564
30	7939	.89977	44	675	8508	54	491	7454
35	7857	.89531	45	655	8395	55	473	7351
36	7839	.89426	46	637	8292	60	388	6856
37	7818	.89310	47	619	8190	65	303	6352
38	7800	.89214	48	602	8093	70	262	6109
39	7779	.89092	49	585	7996	80	185	5646
40	7759	.88984	50	567	7892	90	161	5499

* A table giving the logarithm of the radius for various latitudes and azimuths is appended to this paper. The uncertainties in the figure of the earth make the sixth place of the logarithms unreliable.

† For the centigrade scale and millimetres of pressure—

$$\theta_0=282^\circ.1 \qquad \theta=272^\circ.8+\tau \text{ and } \alpha=\frac{[6.01981]\,\beta}{272.8+\tau}$$

h = elevation of observing-station above the sea-level;

$y = \dfrac{h}{m_0 \, r_0}$ and $m = \dfrac{(1-y)^6}{1 + m_0 \, y} \cdot \dfrac{a_0}{a} \cdot m_0$; also $v = \dfrac{5a}{m}$;

$\rho = r_0 + h$;

d = horizontal linear distance between the two stations at the sea-level, expressed in metres;

$\psi = \dfrac{d}{r_0}$ = distance in parts of radius or $\dfrac{[5.3144251]\, d}{r_0}$ in seconds of arc;

Δh = difference of height;

ζ = observed zenith-distance; and

$$p = \frac{m\,(\cos^2 \zeta + 1 - v)}{\cos^2 \zeta}$$

$$\Delta h = \rho\, \psi \left\{ \cot \zeta + \frac{\cos^2 \zeta + 1 - v}{2 \sin^2 \zeta}\, \psi + \frac{2\, v \cot \zeta}{3\, m \sin^2 \zeta}\, \psi^2 + \frac{v\,(p-3) \cot^2 \zeta}{6\, m^2 \sin^2 \zeta}\, \psi^3 + \dots \right\}$$

H = elevation of observed station $= h + \Delta h$

Applying these formulæ to the hourly observations of zenith-distances, we obtain the following resulting values for difference of height:

Hour.	Δh from observations at— Bodega Head.	Ross Mountain.	Mean Δh	
	m.	m	m.	
7 a. m.	+600.365	−596.374	598.370	
8 a. m.	599.881	597.126	.503	
9 a. m.	598.623	598.014	.318	
10 a. m.	598.578	598.081	.329	
11 a. m.	599.119	598.115	.617	
Noon	599.161	597.896	.528	
1 p. m.	599.489	597.762	.625	
2 p. m.	599.374	597.325	.350	
3 p. m.	599.525	597.538	.531	
4 p. m.	599.576	597.851	.714	
5 p. m.	600.508	597.458	.983	
Means	+599.473	−597.595	598.533	m. ±0.041

These results are shown graphically on the accompanying diagram, which also gives a representation of the observed pressure and temperature of the air at the two stations.

It will be seen that the accord with the result from the leveling-operation is quite close, the difference only amounting to $0^{m}.21$; but if we compare the results derived from the two stations separately, we have a difference of $1^{m}.88$, which reduces to $1^{m}.36$ if we confine ourselves to the hours between 9 and 4, both inclusive. This would indicate that the adopted constant of refraction requires a small change to suit the particular circumstances. The observations at Bodega Head give too much difference of height, and the observations at Ross Mountain too little difference of height. In either case, the constant employed makes the ray of light pass above the true height, which indicates that the adopted radii of curvature of the ray are too great, or that the assumed refraction is too small. If we increase a_0 or v by one-ninth of its value, we find results which, in their mean values, are almost identical, viz, from observations at Bodega Head, $598^{m}.69$; from Ross Mountain, $598^{m}.35$; mean, $598^{m}.52$; and after omitting results for the hours 7 and 8 a. m. and 5 p. m., when the atmosphere is too much agitated by currents, from observations at Bodega Head, $598^{m}.40$; from Ross Mountain, $598^{m}.58$; mean, $598^{m}.49$. The character of the curves, as given

on the diagram, remains the same for any small change in a_0, but the investigation of the angles of refraction makes the desirability of any such change a matter of doubt.

Let—

Z and Z′ = the true zenith-distances at the lower and upper stations, refraction having no existence;

H and H′ = the known (by level) elevations of the two stations; also $H_0 = \frac{1}{2}(H + H')$; and $d\ \psi\ r_0$ = the same quantities as before.

Then the values of Z and Z′ can be found from the expressions—

$$\tfrac{1}{2}(Z' + Z) = 90^\circ + \tfrac{1}{2}\psi$$

$$\tfrac{1}{2}(Z' - Z) = \tan^{-1}\left\{\frac{H' - H}{d}\left(1 - \frac{H_0}{r_0} - \frac{d^2}{12 r_0^2}\right)\right\}$$

And the angles of refraction become—

$$\varDelta\zeta = \zeta - Z;\ \text{also the total refraction } r = \varDelta\zeta + \varDelta\zeta'$$
$$\varDelta\zeta' = \zeta' - Z' \qquad\qquad = \psi + 180^\circ - (\zeta + \zeta')$$

In our case Z = 88° 34′ 32″.9 and Z′ = 91° 37′ 36″.1.

The following table contains the resulting refraction for the hourly measures:

Hour.	180° −(ζ+ζ′)	r	Observed angle of refraction at— Bodega Head.	Observed angle of refraction at— Ross Mountain.
	′ ″	′ ″	′ ″	′ ″
7 a. m......	−9 22. 1	2 46. 9	1 21. 1	1 25. 8
8 a. m......	34. 4	34. 6	15. 9	18. 7
9 a. m......	55. 5	13. 5	3. 8	9. 7
10 a. m......	57. 5	11. 5	2. 8	8. 7
11 a. m......	53. 5	15. 5	7. 6	7. 9
Noon	51. 6	17. 4	7. 9	9. 5
1 p. m......	47. 8	21. 2	10. 8	10. 4
2 p. m......	44. 5	24. 5	9. 9	14. 6
3 p. m......	44. 8	24. 2	11. 5	12. 7
4 p. m......	46. 7	22. 3	12. 1	10. 2
5 p. m......	33. 7	35. 3	20. 8	14. 5

The values for the total refraction, r, show the ordinary diurnal variation, the refraction being least soon after 10 a. m., as exhibited in the second figure of the accompanying diagram, where, however, the value of $\frac{1}{2}r$ is represented.

These results from the observed refractions present the anomaly of the refraction at the upper station being greater than the simultaneous refraction at the lower station, except at the afternoon-hours 1, 4, and 5, when the reverse takes place.

Owing to this fact, we do not think it advisable to make any change in the value of a_0.

The angle of refraction for any particular state of the atmosphere with respect to pressure and temperature may be found from the following expressions given by Bauernfeind:

$$\varDelta\zeta = \tfrac{1}{2}v\psi\left\{1 - \frac{4v - m(5 - 6v)}{3v}p_0\psi - (\tfrac{1}{3}p + 1)p_0^2\psi^2 - \ldots\ldots\right\}$$

$$\varDelta\zeta' = \tfrac{1}{2}v\psi\left\{1 - \frac{8v + m(5 - 6v)}{3v}p_0\psi - (p - 5)p_0^2\psi^2 - \ldots\ldots\right\}$$

for the lower and upper stations; also the difference of refraction:

$$\varDelta\zeta - \varDelta\zeta' = \tfrac{1}{3}p_0\psi^2\left\{2v + m(5 - 6v) + v(p - 9)p_0\psi + \ldots\ldots\ldots\right\}$$

where $p_0 = \dfrac{\cot\zeta}{m}$ and $p = \dfrac{m(\cos^2\zeta + 1 - v)}{\cos^2\zeta}$ as before.

Applying these formulae, the angles of refraction at the lower station should be greater by $1''.1$ than the corresponding angles at the upper station.

The cause of the apparent anomaly of an observed greater refraction at the upper than at the lower station may be due to difference of station-errors or of that part of the deviation of the plumb-line which is effective in the vertical planes passing through the two stations. This cause would be a constant one. Or it may be due to a difference in the law of decrease of temperature with increase of height. Thus, the more rapid the decrease of temperature, the smaller the refraction, and, on the contrary, the slower the decrease of temperature, the greater the refraction. With a sufficiently rapid decrease of temperature the refraction may become zero, (and even be negative;) with no decrease, or for a constant temperature, the refraction is very large, and will yet increase should the temperature increase (with the height) instead of decrease. Winds at different altitudes, the currents having different temperature, sufficiently explain such occurrences.

Small defects in the absolute value of the atmospheric temperature are of little consequence with regard to measures of height; thus an increase or decrease of 10° Fahrenheit would only produce an increase or decrease of $0^m.14$ in the difference of height of Bodega Head and Ross Mountain.

In using the ordinary simple expressions for difference of height, taking the ray of light to be part of an arc of a circle, or the refractions equal at the two stations, which answer well enough for short distances and small heights, a knowledge of the so-called co-efficient of refraction (k) may often be desirable; it is nearly $\frac{1}{2}\,v$, and may be found for any particular pressure and temperature of the atmosphere by—

$$2\,k = v\,(1 - 2\,p_o\,\psi + (2 - \frac{2}{3}\,p)\,p_o^2\,\psi^2 \ldots\ldots\ldots\ldots)$$

the letters having the same signification as before. In the present case we can find for 9 a. m., at the Bodega Head station, $k = 0.088$, whereas for that hour the reciprocal and simultaneous zenith-distances* give $k = 0.092$, as found by—

$$k = \frac{1}{2} + \frac{180 - (\zeta + \zeta')}{2\,\psi}$$

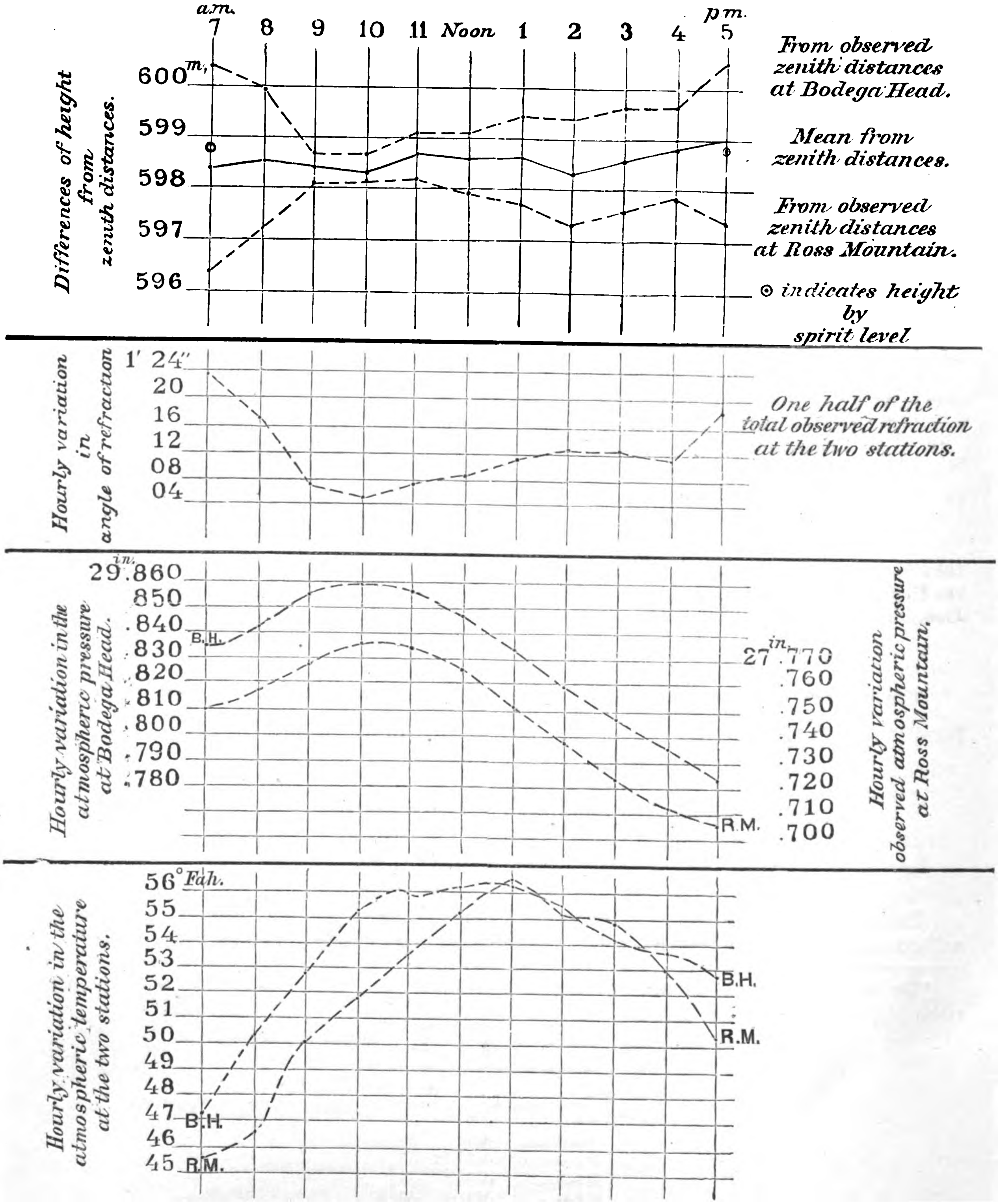
The following table contains the values of $\frac{1}{2}\,v$ for latitude 38° and for various atmospheric pressures and temperatures:

Pressure.	30° F.	50° F.	70° F.	90° F.
30 inches......	0.094	0.090	0.087	0.084
28 inches......	0.088	0.084	0.081	0.078
26 inches......	0.082	0.078	0.075	0.073
24 inches......	0.076	0.073	0.070	0.067

Further and more extended observations for the daily variation of refraction have been authorized by the Superintendent, and it is to be hoped that these may soon be made.

* The values of k for each hour and the values of Δh found by $\frac{d \sin \frac{1}{2}(\zeta' - \zeta)}{\cos \frac{1}{2}(\zeta' - \zeta + \psi)}$ are contained in the following table:

Hour.	k	Δh
		m.
7 a. m......	0.114	598.48
8 a. m......	.106	.59
9 a. m......	.092	.42
10 a. m......	.090	.42
11 a. m......	.093	.72
12 a. m......	.094	.65
1 p. m......	.097	.76
2 p. m......	.099	.48
3 p. m......	.099	.67
4 p. m......	.098	598.84
5 p. m......	.106	599.08
Mean....	0.099	598.64 ± $0^m.04$


a.m. 7
8
9
10
11
Noon
1
2
3
4
p.m. 5
Differences of height from zenith distances.
600m
599
598
597
596
From observed zenith distances at Bodega Head.
Mean from zenith distances.
From observed zenith distances at Ross Mountain.
⊙ indicates height by spirit level
Hourly variation in angle of refraction
1' 24"
20
16
12
08
04
One half of the total observed refraction at the two stations.
Hourly variation in the atmospheric pressure at Bodega Head.
29in.860
850
.840
.830
.820
.810
.800
.790
.780
B.H.
R.M.
27in.770
.760
.750
.740
.730
.720
.710
.700
Hourly variation observed atmospheric pressure at Ross Mountain.
Hourly variation in the atmospheric temperature at the two stations.
56° Fah.
55
54
53
52
51
50
49
48
47
46
45
B.H.
R.M.

3.—RESULTS OF HOURLY OBSERVATIONS OF THE ATMOSPHERIC PRESSURE FOR DIFFERENCE OF HEIGHTS OF THE STATIONS.

In the present state of barometric hypsometry it is most desirable to make and discuss barometric observations specially undertaken with a view of contributing information respecting the daily and the annual variation in deduced heights. It is only by means of such observations, made in different climates and under different circumstances, that we can secure the foundation for corrections to be applied to computed differences of heights measured barometrically at *any hour* of the day and *any season* of the year.

Ramond, about 1810, appears to have been the first to notice the relation between barometrically-deduced heights and the time of the day when these measures were taken. The annual variation was also indicated by his results. Kreil proposed the use of annual means of pressure and temperature to secure reliable results, especially for the case when the two stations lie horizontally a great distance apart.

Among those who have more recently occupied themselves with this subject may be mentioned Professor Plantamour, Dr. Bauernfeind, Dr. Rühlmann, and Major Williamson, U. S. A. Plantamour's Tables of Corrections have been reproduced in the Meteorological and Physical Tables, published by the Smithsonian Institution, (third edition, 1859.) Further information will be found in Rühlmann's small but valuable work: "The Barometric Measurements of Heights and their Relation to the Constitution of the Atmosphere," Leipzig, 1870.*

Among the conclusions reached are the following: Differences of heights, barometrically determined, appear to attain their maximum value shortly before the time of greatest heat of the day; they decrease rapidly during the afternoon, and slowly during the night, reaching their minimum about one or two hours before sunrise. From the least to the greatest value the rise is rapid. This daily variation in the computed heights appears fully developed only for those days on which the insolation of the ground is complete under a clear sky, and the loss of heat during the night by radiation is not interrupted. On cloudy or windy days the amplitude of the variation is much diminished, without, however, totally disappearing. The magnitude of the daily variation, besides being dependent on the season of the year, is affected by local circumstances, connected with the capacity of the ground for absorption and radiation of heat. Resulting heights, determined from daily or monthly means, also show an annual period; they are found too small in winter and too great in summer. The amplitude of the annual variation is less than that of the daily variation. Heights determined from annual means generally give results differing little from the truth.

Observations are recommended to be made at the following hours, when the daily and annual variations are supposed to pass through zero-value:

In January, at 1 p. m.
In February, at 10 a. m. and 4 p. m.
In March, at 8 a. m. and 6 p. m.
In April, at 7½ a. m and 7 p. m.
In May, at 7 a. m. and 7 p. m.
In June, at 6½ a. m. and 9½ p. m.
In July, at 6½ a. m. and 9½ p. m.
In August, at 7 a. m. and 7½ p. m.
In September, at 8 a. m. and 6 p. m.
In October, at 10 a. m. and 3½ p. m.
In November, at 10½ a. m. and 2½ p. m.
In December, at no time.

These hours refer to the middle of each month and to an average state of the atmosphere, and must be considered as correct only for the actual circumstances under which they were obtained; how far they apply to our various climatic conditions remains to be ascertained experimentally.

The recognized cause of the daily variation in the computed differences of heights is the defect

* This pamphlet contains a historical sketch of the development of barometric hypsometry, and includes a compilation of the principal barometric formulae offered by various writers, chronologically arranged; also a table of the literature of this branch of meteorology.

ive mean temperature introduced by the supposition that the mean of the observed temperatures at the two stations equals that of the intervening stratum of air. The daily variation of temperature, under a clear sky, is less the higher we rise above the surface, and is very small in the higher strata. The thermometers, which cannot be elevated sufficiently to place them above the influence of the radiation and conduction of the soil, can, therefore, give but very defective information respecting the temperature of the elevated strata of air, except in the case of an overcast sky. The problem of barometric measures has, therefore, been inverted, and the mean temperature of the air has been computed from the observed pressures, and the difference of altitudes otherwise known or determined. This process leads to a system of corrections to the observed temperatures to be applied in the computation of ordinary hypsometric measures by means of the barometer.

It matters comparatively little which of the generally-recognized barometric formulae is used; or the case in hand we select from the class of formulae which introduce a distinct term for observed humidity, that given by Dr. Rühlmann, for which see his work on Barometric Measurements of Heights, (Leipzig, 1870,) or Astronomical Tables and Formulae, by Dr. C. F. W. Peters, (Hamburg, 1871.) Plantamour's and Bauernfeind's formulae give almost identical results, which, in the present case, are about three-fourths of a metre in excess; on the other hand, Laplace's, Baily's, and Loomis' formulae, all based upon an average degree of humidity, give results about one and one-half metre in defect of the result by Rühlmann's formula. The effect on the calculated height of the term, involving the hygrometric state of the air, is comparatively small; in the present case the result for complete saturation being $2^{m}.7$ greater than the results supposing absolute dryness.

Let—

h = difference in height, expressed in metres;

b', b'' = atmospheric pressure at the lower and upper stations, both readings reduced to refer the temperature of the mercury to that of freezing water; in the term involving the vapor pressure b' and b'' should be expressed in millimetres;

t', t'' = atmospheric temperature, expressed in centigrade scale, at the lower and upper stations;

σ', σ'' = the vapor-pressure, expressed in millimetres, at the lower and upper stations;

z = height of lower station above the sea-level; and

φ = mean latitude of the stations:

then—

$$h = 18400.2 \left(1.00157 + 0.003675 \frac{t' + t''}{2}\right)\left(1 + 0.378 \frac{\frac{\sigma'}{b'} + \frac{\sigma''}{b''}}{2}\right)$$

$$\times (1 + 0.002623 \cos 2\varphi) \left(1 + \frac{2z + h}{6378150}\right) \log \frac{b'}{b''}$$

The logarithms of these terms are tabulated,* and putting for convenience—

$$\log \left\{18400.2 \left(1.00157 + 0.003675 \frac{t' + t''}{2}\right)\right\} = \mathrm{A}$$

$$\log \left\{\log b' - \log b''\right\} = \mathrm{B}$$

$$\log \left\{1 + \frac{0.378}{2}\left(\frac{\sigma'}{b'} + \frac{\sigma''}{b''}\right)\right\} = \mathrm{C}$$

$$\log \left\{1 + 0.002623 \cos 2\varphi\right\} = \mathrm{D}$$

$$\log \left\{1 + \frac{2z + h}{637815}\right\} = \mathrm{E}$$

we have—

$$\log h = \mathrm{A} + \mathrm{B} + \mathrm{C} + \mathrm{D} + \mathrm{E}$$

If T and T′ = temperature of dry and wet bulb, e = maximum vapor-tension at T′; then

$$\sigma = e - 0.0008\,(\mathrm{T} - \mathrm{T}')\,b$$

and in case the wet bulb is coated with ice,

$$\sigma = e - 0.00069\,(\mathrm{T} - \mathrm{T}')\,b$$

*Rühlmann's Table I (also that given in Peters' tables) requires a small correction, easily applied, in the last place of decimals, to produce perfect accord with the numbers in the formula. It has been supplied in the present application.

The mean value of σ or $\frac{\sigma' + \sigma''}{2}$ and the mean pressure $b = \frac{b' + b''}{2}$ form the arguments for the table giving the value of C with sufficient approximation.

The following table contains the resulting differences of height between Bodega Head and Ross Mountain for each of the observing-hours, and their excess (indicated by a minus sign) over the true difference, as found by the spirit-level:

Hour.	h	598.74 − h
	m.	*m.*
7 a. m......	598.80	− 0.06
8 a. m......	600.98	− 2.24
9 a. m......	605.52	− 6.78
10 a. m......	607.65	− 8.91
11 a. m......	608.84	− 10.10
Noon	609.17	− 10.43
1 p. m......	610.34	− 11.60
2 p. m......	609.73	− 10.99
3 p. m......	608.94	− 10.20
4 p. m......	607.98	− 9.24
5 p. m......	604.32	5.58

The small effect of variations in moisture in these results has already been stated; to ascertain effects of small changes in pressure and in temperature we have—

$$d\,h \doteq h\,\left\{\frac{a\,d\,\tau}{1 + a\,\tau} + \mathrm{M}\,\frac{d\,b'}{\log b' - \log b''}\left(\frac{1}{b'} + \frac{1}{b''}\right)\right\}$$

where—

$\tau = \frac{1}{2}\,(t' + t'')$;
$a = 0.003675$;
M = modulus of common logarithms; and
$d\,b'' = -\,d\,b'$.

Supposing an error in the reading of the barometers of 0.004 inch, or 0.1 millimetre nearly, to have been committed at each of the stations, (but of opposite signs,) we find $dh = 2.3$ metres; hence, in the mean value from five days of observations we may expect a remaining uncertainty of nearly one metre.

Supposing an error in the reading of the thermometer of $\frac{1}{3}$° Fahrenheit, nearly 0°.2 centigrade, we have $dh = 0.4$ metre, showing that the uncertainty in any one of the above hourly results arising from imperfect readings of instruments may be taken as $\frac{1}{600}$ of the height nearly.

The computed differences of height for each hour are shown in the accompanying diagram, to which has been added the resulting vapor-pressure at the two stations, as computed from Major Williamson's table.* The deduced vapor-pressures, as well as the observed temperatures at the two stations, are strictly local results, and give no true indication of the humidity and temperature of the intervening stratum of air.

The true difference of height and the pressure at the two stations being known, we find the mean temperature of the air depending upon these data by—

$$\tau = \frac{1}{a}\left(\frac{h}{k\,(\log b' - \log b'')} - 1\right)$$

where k represents the constant in the approximate expression—

$$h = k\,(1 + a\,\tau)\log\frac{b'}{b''}$$

But it is more convenient and accurate to make use of the tables, forming the values $\frac{\log h}{\mathrm{B} + \mathrm{C} + \mathrm{D} + \mathrm{E}}$, and entering the first table, which gives the value of $2\,\tau$ directly. Converting the hourly values of

* Professional Papers of the Corps of Engineers, United States Army, No. 15, New York, 1868.

τ so found into their equivalents in Fahrenheit degrees, we obtain the following numbers:

Hour.	Observed mean temperature at Bodega Head and Ross Mountain.	Computed temperature of intervening stratum of air.	Apparent temperature correction.	Correction by Plantamour's table.
	°	°	°	°
7 a.m......	46.4 F.	46.4 F.	0.0 F.	+1.0 F.
8 a.m......	48.4	46.4	−2.0	−0.6
9 a.m......	51.4	45.6	−5.8	−2.6
10 a.m......	53.4	46.0	−7.4	−4.2
11 a.m......	54.7	46.2	−8.5	−5.1
Noon	55.6	46.8	−8.8	−5.8
1 p.m......	56.3	46.4	−9.9	−6.0
2 p.m......	55.2	46.0	−9.2	−5.5
3 p.m......	54.5	45.9	−8.6	−4.6
4 p.m......	53.2	45.7	−7.5	−3.3
5 p.m......	51.4	46.6	−4.8	−2.0

The numbers in the last column are interpolations from Plantamour's Table XI, p. D. 82, of third edition of the Smithsonian Meteorological and Physical Tables; they refer to March 24, and were converted into degrees of Fahrenheit.

We thus arrive at the remarkable result that the temperature of the intervening stratum of air is nearly constant, viz, 46°.2, and shows apparently no trace of a daily variation, the rays of the sun passing through without sensibly heating it. The daily variation of temperature, therefore, would seem to be confined mainly to the layer of air in contact and close proximity to the earth's surface. The corrections derived from Plantamour's table (deduced from observations at Geneva and the great Saint Bernard) are smaller than those deduced from our observations, but the latter refer to a clear sky, (the heliotropes having been seen every hour.) To make Plantamour's corrections answer for our case, they require to be increased by two thirds of their amount; for the case of an overcast sky they must be diminished possibly by one-half or more. The one-third of the total solar radiation, which may be absorbed by the atmosphere, is probably consumed by the processes of expansion and evaporation, and thus gives no sensible heat. In the present case, however, the daily variation of temperature is very small, owing to the proximity of the ocean, and different and apparently less anomalous results may be expected for stations farther removed from the coast.

To estimate the effect of a small error in the observed pressure on the deduced mean temperature, and supposing, as before, $d\,b'' = -\,d\,b'$, we have from—

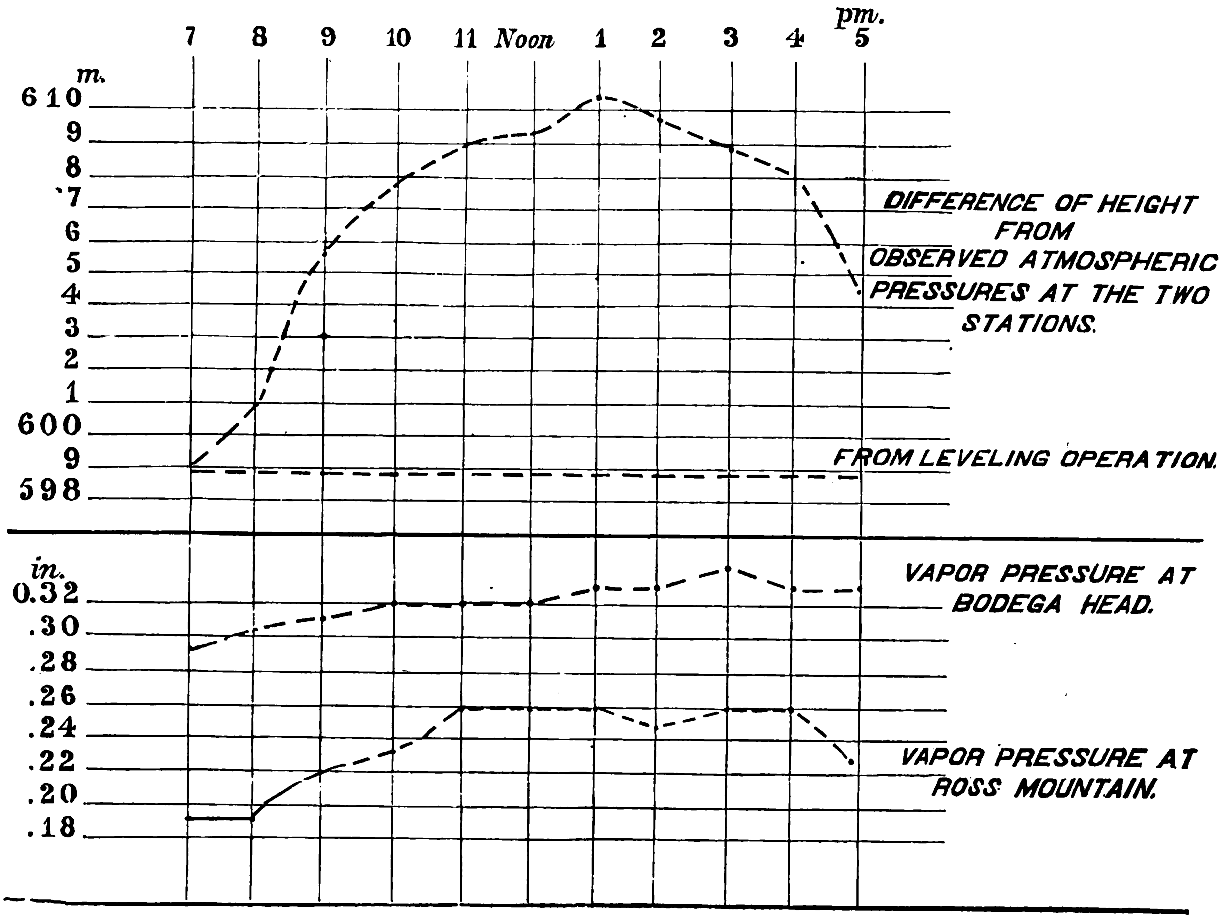
$$d\,\tau = \frac{M\,(1 + \alpha\,\tau)}{\alpha\,(\log b' - \log b'')}\left(\frac{1}{b'} + \frac{1}{b''}\right) d\,b'$$

the relation $d\,\tau = 10.8\,d\,b'$; hence, for $d\,b' = 0.1$ millimetre, $d\,\tau = 1^{\circ}.1$ centrigade, or nearly 2° Fahrenheit, which shows the extreme sensitiveness of the operation.

If the barometric observations *alone* had been available, the safest result that might have been deduced from them would have been that interpolated for the epoch $7\frac{3}{4}$ a. m., which is $600^{m}.5$, and $1^{m}.8$ in excess of the true value.

Table of logarithms of radius of curvature to the earth's surface, for various latitudes and azimuths, based upon Clarke's ellipsoid of rotation (1866), and for metric unit.

	Azimuth.	LATITUDE.						
		24°	26°	28°	30°	32°	34°	36°
	°							
Meridian.....	0	6. 802479	6. 802597	6. 802722	6. 802852	6. 802988	6. 803129	6. 803274
	5	2498	2615	2739	2869	3004	3145	3289
	10	2553	2669	2791	2919	3052	3190	3332
	15	2644	2756	2875	3000	3130	3265	3404
	20	2766	2875	2990	3111	3236	3366	3500
	30	3093	3192	3296	3405	3518	3636	3757
	40	3496	3580	3671	3766	3864	3967	4072
	50	3923	3994	4070	4150	4233	4319	4407
	60	4325	4384	4446	4512	4580	4650	4723
	70	4653	4702	4753	4807	4863	4921	4980
	75	4776	4822	4869	4918	4969	5022	5076
	80	4867	4909	4953	4999	5047	5097	5148
	85	4923	4963	5006	5049	5096	5143	5192
Perpendicular	90	6. 804942	6. 804981	6. 805023	6. 805066	6. 805112	6. 805159	6. 805207
		38°	40°	42°	44°	46°	48°	50°
Meridian.....	0	6. 803422	6. 803573	6. 803726	6. 803880	6. 804035	6. 804189	6. 804342
	5	3436	3586	3739	3892	4045	4199	4351
	10	3478	3626	3775	3926	4077	4228	4378
	15	3546	3690	3835	3982	4130	4277	4423
	20	3637	3776	3917	4059	4201	4343	4484
	30	3880	4006	4133	4262	4391	4519	4647
	40	4179	4289	4400	4511	4623	4735	4846
	50	4498	4590	4683	4777	4871	4965	5058
	60	4797	4873	4949	5025	5104	5181	5257
	70	5041	5104	5166	5229	5293	5357	5420
	75	5133	5190	5248	5307	5364	5423	5481
	80	5201	5254	5308	5363	5417	5472	5526
	85	5242	5294	5345	5397	5450	5502	5554
Perpendicular	90	6. 805256	6. 805307	6. 805358	6. 805409	6. 805460	6. 805512	6. 805563



7 8 9 10 11 Noon 1 2 3 4 pm. 5
m.
610
9
8
7
6
5
4
3
2
1
600
9
598
DIFFERENCE OF HEIGHT FROM OBSERVED ATMOSPHERIC PRESSURES AT THE TWO STATIONS.
FROM LEVELING OPERATION.
in.
0.32
.30
.28
.26
.24
.22
.20
.18
VAPOR PRESSURE AT BODEGA HEAD.
VAPOR PRESSURE AT ROSS MOUNTAIN.

APPENDIX No. 12.

REPORT ON THE LEVELING OPERATIONS BETWEEN KEYPORT, ON RARITAN BAY, AND GLOUCESTER, ON THE DELAWARE RIVER, TO DETERMINE THE HEIGHT ABOVE MEAN TIDE OF THE PRIMARY STATIONS BEACON HILL, DISBOROUGH, STONY HILL, MOUNT HOLLY, AND PINE HILL, BY RICHARD D. CUTTS, ASSISTANT, COAST SURVEY, IN CHARGE OF SECONDARY TRIANGULATION.

HEIGHTS ABOVE MEAN TIDE DETERMINED BY THE SPIRIT-LEVEL.

The leveling was executed in 1870 by Charles Ferguson, esq., Sub-assistant, United States Coast Survey.

The line started from mean tide at Keyport, on Raritan Bay, and, following the route most convenient for determining the height of the primary stations, ended at mean tide of the Delaware River at Gloucester City. The route pursued was not, therefore, the most direct; the one preferred being that on which the longest extent of turnpike and railroad-track could be made available. The length of the main line was seventy-seven miles, and of the offsets, thirteen miles; the total distance leveled and releveled, one section after the other, being one hundred and eighty miles.

The observations are contained in ten volumes. These latter will show the different sections into which the main line was divided; the offsets to the triangulation-stations Beacon Hill, Disborough, Stony Hill, and Mount Holly; also, the offsets to the barometer-stations; and, finally, the height above mean tide of the bench-marks established at the villages through which the line passed.

An additional line of levels was run in 1871 by Mr. B. A. Colonna, aid United States Coast Survey, to connect the triangulation and barometer station Pine Hill with the bench-mark at Gloucester City.

TIDAL STATIONS.

A tide-staff was set up at Keyport and another at Gloucester City, and the tides were observed at each station during a half-lunation for the purpose of determining the level of mean tide. This level, or the computed half-tide mark on the staff, was then transferred to a permanent bench-mark established in the vicinity of each tide-gauge; these two bench-marks being the termini of the line of levels.

INSTRUMENTS.

The instrument used was a pivot-level made by Würdemann. The telescope possessed a magnifying power of 30, was provided with a reticule of three fixed horizontal wires about 4′ apart, and of two vertical wires, and with a riding-level, a division of which represented 3″ in arc at the average temperature at which the instrument would be used in the field.

The leveling-rod was made of seasoned Honduras mahogany and painted white; was $3^{m}.2$ in length by $0^{m}.06$ in width and $0^{m}.04$ in thickness; and was provided with a wooden handle attached to the back part, about 5.6 feet above the bottom, and by means of which the rod could be carried and held in position, and, with two small levels, fixed at right angles, to secure its verticality. To prevent displacement, or change of level, when the rod was turned round for the back sight, the foot of the rod, incased in brass, terminated in a cylindrical button, fitted to and moving freely in the socket of the iron foot-plate on which it rested. This plate, six inches in diameter, was armed underneath with sharp pointed legs, so that when it was dropped by the rod-man on reaching his station, it could be firmly planted in the ground by a stamp or two of the foot. A light chain, with a ring as a handle, was attached to the plate, by which the latter could be readily taken up

and carried forward by the rod-man. Three of such rods and foot-plates accompanied the leveling-instrument, two sets for constant use and the other held as a reserve.

The rods were divided to centimeters, the divisions and comparisons having been made at the Coast Survey Office in Washington.

FIELD OBSERVATIONS AND RECORDS.

The first operation consisted in determining the values of the instrumental constants, viz:

1. Of a division of the level;
2. Of the angular distance between the horizontal wires; and
3. Of the reduction of the mean of the three wires to the middle wire.

By means of these constants, tables were made out, which gave, by inspection,

A. The distance of the instrument to the rod;

B. The correction to reduce the mean of the three wires to the middle wire;

C. The correction on account of the want of level at the moment of observation, and of the daily recorded instrumental errors; and

D. The correction for difference of distance between the back and fore sights.

The order in which the observations were made and recorded, and the directions followed in conducting the operation, may be stated as follows:

I. An adjustment of the instrument, either complete or closely approximate, with all the details duly entered in the record.

This adjustment was made at the commencement and end of each day's work, and consisted—

a. In making the axis of the level parallel with the optical axis of the telescope;

b. In making the axis of the level perpendicular to the vertical axis of the instrument; and

c. In bringing the middle horizontal wire and the middle of the two vertical wires in the optical axis of the telescope.

When this adjustment was approximate only, Tables B and C enabled the computer to apply the necessary corrections to the results of the day's leveling.

II. The placing of the instrument midway, and, if possible, in line between the two rods. In cases where the distance between the back and fore sights was necessarily or by accident unequal, as shown by the recorded differences between the extreme wires, Table D supplied the correction to be applied on account of the resulting inequality of curvature and refraction.

III. The protection of the instrument from the direct rays of the sun by a cap when carried and an umbrella when in use.

IV. The adjustment for verticality of axis; of the focus for distinct vision; of the bubble to the middle of the tube and the recording of the divisions as shown by the eye and object ends; the reading of the heights on the rod crossed by the three wires, and the second reading and recording of the level-bubble. Table C supplied the correction for the difference between the readings of the two ends of the bubble.

V. Bench-marks were established at the end of each day's work, at the different villages through which the line was carried, and whenever from any cause the leveling was suspended.

The details of the work were carried out in conformity with the order and principles contained in instructions specially prepared for the instrument used and the object in view, under the four following headings:

1. Tide-gauge, records, and tidal-station or bench-mark.
2. Adjustment of the instrument.
3. Formulæ, constants, and corrections.
4. General directions for running a line of levels.

The releveling was required, not merely for the sake of verification, but for precision, as it is a well-established fact that there will be always a difference, irrespective of instrumental and personal errors, between the results obtained by the leveling of a line in one direction, and then back again to the starting-point.

The heights will be given in all cases above the mean tide of Raritan Bay; the description of the principal bench-marks is given in the records.

Since the Annual Report of 1870 was published, in which the preceding part of the report of Assistant Richard D. Cutts appeared, one of the sections of the main line and one of the offsets, in each of which there was a discrepancy between the forward and back measurements, have been releveled by Sub-assistant John N. McClintock, and a revision made at the office of the results as well from the barometric as from the spirit-leveling observations.

The following table contains the heights, above the half-tide level, of the different bench-marks which were established on the main line from Keyport, on Raritan Bay, to the Delaware River, at Gloucester City, three miles below Philadelphia:

TABLE I.

Main line bench-marks.	Forward measurement.	Back measurement.	Height above half-tide.	
	Meters.	*Meters.*	*Meters.*	*Feet.*
The 13-foot mark on staff above half-tide	....	....	2.518	8.26
Thence to bench-mark, Morris House, Keyport	+ 2.274	2.276	4.793	15.73
Thence to bench-mark, Tuttle's gate, Matteawan	+11.997	11.976	16.780	55.05
Thence to bench-mark, Clarke's house, Morgansville	+34.250	34.212	51.011	167.36
Thence to bench-mark, Frazier's house, Morgansville	+ 1.461	1.460	52.472	172.16
Thence to bench-mark, Holmdel Cross-Roads	−11.464	11.466	41.007	134.54
Thence to bench-mark, Rossell, Freehold	+ 9.615	9.655	50.642	166.15
Thence to bench-mark, Mount's Corner, West Freehold	+ 5.129	5.157	55.785	183.02
Thence to bench-mark, Parker's old house	− 3.565	3.384	52.312	171.63
Thence to bench-mark, Burnt Tavern Cross-Roa ls	+11.617	11.219	63.730	209.09
Thence to bench-mark, Allen, Claksburgh	− 0.771	0.713	62.988	206.66
Thence to bench-mark, Tunis, Imlaytown	+ 6.579	6.497	69.526	228.11
Thence to bench-mark, Giberson, Imlaytown	−21.639	21.636	47.889	157.12
Thence to bench-mark, Hornerstown	−22.476	22.490	25.406	83.35
Thence to bench-mark, Cookstown	+ 4.674	4.728	30.107	98.78
Thence to bench-mark, Wrightstown	+11.411	11.407	41.516	136.21
Thence to bench-mark, Lewiston	−15.727	15.651	25.827	84.73
Thence to bench-mark, Pemberton	−12.895	12.965	12.897	42.31
Thence to bench-mark, Mount Holly railroad-bridge	− 8.296	8.295	4.602	15.10
Thence to bench-mark, Rodgers's house, Hartford	+10.028	10.035	14.634	48.01
Thence to bench-mark, Hunter, Moorestown	+ 6.322	6.308	20.949	68.73
Thence to bench-mark, Camden court-house, Camden	−11.789	11.791	9.159	30.05
Thence to bench-mark, Buena Vista House, Gloucester	− 5.725	5.754	3.420	11.22
Thence to 12.1-foot mark on tide-gauge, Delaware River	− 0.600	0.600	2.820	9.25
Thence to half-tide, Delaware River	− 1.778	1.778	1.042	3.42

The leveling shows that the half-tide level of the Delaware River at Gloucester City is $1^{m}.04$, or 3 feet 5 inches, above the half-tide level of the ocean, supposing that the level of Raritan Bay is the same as that of the ocean, and that the tides in Delaware River were in their normal state, as believed to have been.

The next table contains the heights above half-tide of the primary stations of Beacon Hill, Disborough, Stony Hill, Mount Holly, and Pine Hill, determined by offsets from the main line.

TABLE II.

Primary-triangulation stations.	Forward measurement.	Back measurement.	Height above half-tide.	
	Meters.	*Meters.*	*Meters.*	*Feet.*
Bench-mark, Morgansville			52.472	172.16
Thence to bench-mark, Beacon Hill station	+ 61.257	61.226	113.713	373.08
Bench-mark, Burnt Tavern			63.730	209.09
Thence to bench-mark, Disborough station	− 13.620	13.674	50.083	164.32
Bench-mark, Hornerstown			25.406	83.35
Thence to bench-mark, Stony Hill station	+ 46.342	46.023	71.588	234.87
Bench-mark, Mount Holly railroad-bridge			4.602	15.10
Thence to bench-mark, Sharpe's Corner	+ 9.034	9.045	13.641	44.75
Thence to bench-mark, Mount Holly station	+ 41.614	41.716	55.306	181.45
Bench-mark, Buena Vista House, Gloucester			3.420	11.22
Thence to bench-mark, Ewen's house	+ 10.367	10.327	13.767	45.17
Thence to bench-mark, Haddonsfield	+ 8.784	8.816	22.567	74.04
Thence to bench-mark, Whitehorse station	− 2.892	2.912	19.665	64.52
Thence to bench-mark, Taggart's house, Clemonton	+ 3.504	3.492	23.163	75.99
Thence to bench-mark, Pine Hill station	+ 38.291	38.241	61.429	201.54

Table III gives the heights above half-tide of the surface of the mercury in the cisterns of the barometers used in the hypsometric operations referred to in Appendix 8 of the Annual Report for 1870, so far as those heights were determined, as in the previous cases, by the spirit-level.

TABLE III.

Bench-marks and barometer-cisterns.	Mean of measurements.	Heights above half-tide.		Barometer-station.
	Meters.	*Meters.*	*Feet.*	
Bench-mark, Stony Hill station	71.588			
Thence to bench-mark, Woodward's house	−14.210			
Thence to cistern of barometer	+ 5.192	62.570	205.29	Stony Hill.
Bench-mark, Sharpe's Corner	13.641			
Thence to bench-mark, Rhee's house	− 1.980			
Thence to cistern of barometer	+ 4.360	16.021	52.56	Mount Holly.
Bench-mark, Buena Vista House, Gloucester	3.420			
Thence to cistern of barometer	+ 7.802	11.222	36.82	Gloucester.
Bench-mark, Taggart's house, Clemonton	23.163			
Thence to cistern of barometer	+ 4.329	27.492	90.20	Pine Hill.

The lines of level were not extended to the triangulation and barometer stations of Mount Rose, Newtown, Willow Grove, Yard, Bethel, and Lippincott, as it was intended to measure the altitude of these stations by the barometer; and with this view, the difference in height between the bench-mark at each station and the cistern of the barometer observed near it, was determined by the spirit-level, and, as usual, by two distinct measurements.

	Meters.
Bench-mark, Mount Rose station, above cistern of barometer	15.639
Bench-mark, Newtown station, above cistern of barometer	12.237
Bench-mark, Willow Grove station, above cistern of barometer	4.876
Bench-mark, Yard station, above cistern of barometer	41.874
Bench-mark, Bethel station, above cistern of barometer	12.674
Bench-mark, Lippincott station, above cistern of barometer	8.019
Bench-mark, Stony Hill station, above cistern of barometer	9.018
Bench-mark, Mount Holly station, above cistern of barometer	39.285
Bench-mark, Pine Hill station, above cistern of barometer	33.937
Bench-mark, Buena Vista House station, above half-tide	3.420
Gloucester cistern of barometer, above half-tide	11.222

In the following table the differences in height determined respectively by the spirit-level and by the barometer are brought together and compared. The barometric results are slightly different from those given in Appendix No. 8, Annual Report of 1870, for the reason that the field-observations taken at 2 p. m. have been excluded, and the differences of height computed from those taken for the middle of July at 6½ a. m. and 9½ p. m.; for the middle of August at 7½ a. m. and 7½ p. m.; and for the middle of September, those taken at 8 a. m. and 6 p. m. The observations at the above epochs of the day—the latter changing with the month—are now believed to represent the atmospheric pressure, with a close approach to its real value.

The maximum difference between the results now given and those published in 1870 is 0.3 of a meter.

TABLE IV.

Barometer-stations.	Difference in height.		Difference.
	Barometer.	Spirit-level.	
	Meters.	*Meters.*	*Meters.*
Stony Hill and Mount Holly	47. 16	46. 55	−0. 61
Mount Holly and Gloucester	7. 06	4. 80	−2. 26
Gloucester and Pine Hill	17. 59	16. 27	−1. 32
Mount Holly and Pine Hill	10. 33	11. 47	+1. 14

From the above comparisons it would appear that the differences given by the barometer may be assumed to be about $0^{m}.75$ greater than by the spirit-level. Hence, in the cases where the altitudes of the stations depend entirely on the barometric differences, it would be but proper to decrease the latter by an amount of at least $0^{m}.5$, and it is with this correction that the following final table is made out.

The table shows the resulting heights, above the half-tide of Raritan Bay, of all the triangulation-stations embraced in the hypsometrical campaign.

TABLE V.

Triangulation-stations.	Height by spirit-level.	Difference by barometer.	Reduction to triangulation-station, by spirit-level.	Height of stations above half-tide.	
					Mean.
	Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*
Beacon Hill	113. 73				113. 73
Disborough Hill	50. 08				50. 08
Stony Hill	71. 59				71. 59
Mount Holly *	55. 31				55. 31
Pine Hill	61. 43				61. 43
Mount Rose, from Stony Hill		49. 10	78. 21	127. 31	127. 66
Mount Rose, from Mount Holly		96. 35	31. 66	128. 01	
Newtown, from Stony Hill		24. 27	74. 81	99. 08	99. 45
Newtown, from Mount Holly		71. 55	28. 26	99. 81	
Willow Grove, from Mount Holly		109. 93	20. 90	130. 83	
Willow Grove, from Gloucester		117. 37	16. 10	133. 47	131. 94
Willow Grove, from Pine Hill		99. 16	32. 37	131. 53	
Yard, from Gloucester		97. 27	53. 09	150. 36	150. 36
Bethel, from Gloucester		101. 24	23. 89	125. 13	125. 13
Lippincott, from Gloucester		24. 15	19. 24	43. 39	43. 39

* The difference of heights, Mount Holly—Stony Hill, was also determined by me by means of zenith-distances at Mount Holly. From these we find for height of Stony Hill, $55^{m}.31 + 16^{m}.43 = 71^{m}.74$.

APPENDIX No. 13.

REPORT OF OBSERVATIONS OF THE TOTAL SOLAR ECLIPSE OF DECEMBER 22, 1870, BY GEORGE W. DEAN, ASSISTANT UNITED STATES COAST SURVEY.

FALL RIVER, MASS., *March* 20, 1871.

DEAR SIR: About the 1st of September last I was informed by Professor Peirce, Superintendent of the United States Coast Survey, that my services would be required in making arrangements for observing the total eclipse, in Spain, in December.

The special observations assigned to me were those of precision, and, so far as practicable, the determination of the geographical position from principal eclipse-stations in Spain.

As the expedition was to be under your general directions, I improved an early opportunity of conferring with you in regard to its organization and plans of operation.

Our information relating to the meteorological conditions of the winter-climate of Southern Spain being quite limited, it was deemed advisable that I should, at an early date, proceed to England, and there obtain such information on this subject as might be practicable, and which would prove of great service in selecting the most favorable localities for observing the different phases of the eclipse.

During my stay in England, from the 1st until the 19th of November, I obtained much information in regard to the climate of Southern Spain from the astronomer-royal at Greenwich, Louis P. Cassella, esq., and several other scientific gentlemen in London, to all of whom I was indebted for many courteous attentions.

This information seemed to indicate that the probabilities for fair weather in Southern Spain were more promising near the Atlantic coast than upon the shores of the Mediterranean, from the fact that most of the storms in that section came from the south and east.

Information on this point was sought from the commanders and chief officers of the steamers plying between Southampton and ports in the Mediterranean, and also from gentlemen who, for many years, had resided at Gibraltar, all of whom confirmed the information previously obtained, and which I am gratified to state was also the opinion of Capt. Cecilio Pujazon, director of the observatory at San Fernando, and Capt. José S. Montop, chief of the Spanish Coast Survey, whom we had the pleasure of meeting at San Fernando early in December.

As the center of the path of the total phase would fall near the city of Jerez, which is located about twenty miles northeasterly from Cadiz and ten or fifteen miles from the sea-coast, that point appeared to be one of the most favorable in Spain for observing the eclipse, and accordingly you gave directions that all the instruments and equipments of our expedition should be forwarded from Cadiz to Jerez.

The principal eclipse-station was located about a mile northeasterly from the city, in an olive-grove belonging to Messrs. Davies, who placed their grounds and buildings at the disposal of our party without compensation, and rendered most valuable assistance to all the members of the expedition during our sojourn at Jerez.

The requisite lumber for constructing the small observatory, photographic room, &c., could not at once be obtained, and it was found necessary to have all our boards and scantlings cut from three-inch planks by manual labor. This, with much stormy weather, greatly retarded our preliminary preparations; nevertheless, the work was pressed forward as rapidly as possible, and, at the urgent solicitation of Mr. Willard, the photographic room, and other preparations required by the photographic department, were first completed.

On the 16th of December our small field-observatory was nearly completed, and on that evening good observations for ascertaining the time and latitude were made.

The weather on the two following evenings proved unfavorable; but on the evenings of the 19th, 20th, and 21st, observations for time were obtained, and the corrections and daily rates of the several chronometers were satisfactorily determined.

It may be remarked that the instruments used in ascertaining the local time were a 46-inch transit, with an aperture of 2¾ inches, (U. S. Coast Survey No. 5,) a chronograph-register, (U. S. Coast Survey No. 2,) and two break-circuit chronometers, (Frodsham.)

The transit-instrument was firmly adjusted upon two pine posts, each 8 by 12 inches and 5½ feet in length, which were sunk about 3 feet into the ground.

Meridian-line.—While the preliminary astronomical observations at the Olivar station were being made, a meridian-line was established from a series of observations upon zenith and circum-polar stars with the 46-inch transit, (U. S. Coast Survey No. 5.)

The length of this line was 146.3 meters, and the termini were marked by stone posts, which were sunk about 2½ feet into the ground, and in the top of which small copper bolts were inserted.

Eclipse-observations.—On the day preceding the eclipse, all the instruments and telegraph-apparatus were adjusted in good working order, and a cloudless sky gave flattering promises for the following day; but about midnight clouds began to come from the southwest, and at 2 a. m. the sky was entirely covered, and at intervals the rain fell rapidly until 6 o'clock, when the clouds broke up a little, yet with no positive signs of clearing.

Thus the day opened with gloomy prospects; still, each observer went on perfecting his arrangements, meanwhile watching patiently for views of the sun.

At half past 9 o'clock our hopes of success were well-nigh exhausted, when the rain again began to fall rapidly; fortunately, however, the shower was of short duration, and at 10 a. m. the sky in the immediate vicinity of the sun became quite clear. As the time for the first contact drew near, the recording-apparatus was placed in working order, and I obtained a good observation of the beginning of the eclipse, and a few seconds later a photograph of the sun was obtained by Mr. Willard.

At favorable opportunities during the progress of the eclipse, which continued for two hours and fifty minutes, photographs of the different phases were taken by Messrs. Willard and Gannett, the exact instant of the exposure of each picture being recorded by the chronograph. As these gentlemen will probably present to you a full report of their photographic operations, it is only necessary for me to give the chronographic record of the several photographs, an abstract of which is herewith appended.

The instrument used by me in observing the first contact was a telescope (comet-seeker) equatorially mounted, having a focal length of 33 inches, with an aperture of 3¾ inches and power of 32, for the use of which I was indebted to Prof. C. A. Young.

During the progress of the eclipse, the sun, most of the time, was obscured by clouds, and, as the chronographic record of the photograph required much of my attention, I was unable to note many of the interesting phases of the eclipse.

Two first-class thermometers (made by Cassella, of London) were suspended in the shade upon the north side of our field-observatory, and the temperature was noted every fifteen minutes during the eclipse. At half past 9 a. m. the thermometers indicated 56°, and at 30 minutes past 10, or about five minutes after the beginning of the eclipse, the temperature was 60°. As the eclipse progressed the temperature fell slowly for an hour, and at the time of totality it was 59°, and so continued until the close of the eclipse. Had the weather been clear, the temperature would in all probability have fallen three or four degrees during the eclipse.

Just before the beginning of the total phase, an opening through the clouds enabled me to obtain a good observation of the first inner contact, or time of total immerson, which was recorded by the chronograph.

The formation and rapid disappearance of what are now generally known as "Baily's beads" were noted, and the effect was exceedingly brilliant and startling. These observations were made with a Clark telescope, (comet-seeker,) which was equatorially mounted. Its focal length was

about 36 inches, the aperture 3 inches, and the magnifying power was 25. This instrument is the property of the Harvard College observatory, and I was indebted to you for its use on this occasion.

In watching the different phases of the eclipse, my eyes were protected by colored glasses of different shades, now generally known as "London smoke;" but no shade-glass was used in observing the beginning of totality.

A few minutes preceding the total phase, the force of the wind increased a little and blew in gusts, followed by brief lulls, which at once reminded me that I had before seen a similar phenomenon during the total eclipse which I had the pleasure of observing in Kentucky on the 7th of August, 1869.

Several large glass lanterns had been specially provided for use by the photographers and myself during the totality; but Mr. Willard preferred coal-oil lamps, which, very unfortunately, were not sufficiently protected from the wind, and all his lights were quickly blown out, when a messenger was dispatched for my lantern, which I promptly sent to Mr. Willard. While I was engaged in procuring another light for the purpose of inspecting the chronographic record, the emersion occurred; and, to my great disappointment, I failed to observe the second inner contact, or the ending of the total phase. From this time until the close of the eclipse the sun was seldom visible, on account of dense cumulus and nimbus clouds, which prevented us from observing the fourth, or last, contact.

The day closed with a violent storm of wind and rain; but, fortunately, all our instruments were quickly dismounted and placed under shelter without serious damage.

Observations for ascertaining the latitude of the eclipse-station were made by Capt. O. H. Ernst, United States Engineers; and with the cheerful co-operation of Capt. Cecilio Pujazon, director of the San Fernando observatory, arrangements were made for determining the longitude of the Olivar station, by exchanging time-signals by telegraph, but the unfavorable weather prevented the successful execution of these operations.

Capt. José S. Montop, chief of the Spanish Coast Survey, very kindly offered to connect our eclipse-station with the triangulation of the Spanish surveys; and, in a letter which I have received since I returned to the United States, dated at San Fernando, January 26, Captain Montop informs me that the proposed observations had been completed, and, from his determinations, the geographical position of our eclipse-station, Olivar de Buena Vista, is as follows: Latitude $36° 41' 36''.4$; longitude east of the observatory at San Fernando, $4' 55''.3$, or, in time, $19^s.7$.

In the American Nautical Almanac for 1870, the longitude of the San Fernando observatory is assumed to be $4^h 43^m 22^s.42$ east of the meridian of Washington, which locates the Olivar eclipse-station $4^h 43^m 42^s.1$, east of the observatory at Washington.

In closing this official report, I again desire to express my sincere thanks to Messrs. Davies, at Jerez, for the many civilities received from them; and to Capt. Cecilio Pujazon, director of the San Fernando observatory, also to Capt. José S. Montop, chief of the Spanish Coast Survey, my hearty acknowledgments are hereby presented for the official co-operation and friendly attentions which they extended to the American Eclipse Expedition in Spain.

Yours, very respectfully,

GEO. W. DEAN,
Executive Officer.

Prof. JOSEPH WINLOCK,
Chief of American Eclipse Expedition in Spain.

Abstract of the chronographic record.

JEREZ, SPAIN, *December* 22, 1870.

	Photographs.	Recorded times.			Chronometer-corrections.		Local time.			Remarks.
		h.	*m.*	*s.*	*m.*	*s.*	*h.*	*m.*	*s.*	
	Dean	10	48	42.80	22	56.90	10	25	45.90	At the time of observing the first contact I estimated that the time recorded on the chronograph was three seconds late.—G. W. D.
1	Willard............		48	46.20		56.90		25	49.30	
2	....do		49	54.45		56.90		26	57.55	
3	....do		51	51.30		56.89		28	54.41	
4	....do		53	50.80		56.89		30	53.91	
1	Gannett		55	58.95		56.89		33	02.06	
5	Willard............		56	22.05		56.88		33	25.17	
6	....do	11	00	51.00		56.88		37	54.12	
7	....do		08	53.40		56.86		45	56.54	
2	Gannett		10	07.70		56.85		47	10.85	
8	Willard............		11	13.70		56.85		48	16.85	
9	....do		17	59.30		56.84		55	02.46	
10	....do		22	27.00		56.84		59	30.16	
3	Gannett		22	29.60		56.84		59	32.76	
11	Willard............		26	35.00		56.83	11	03	38.17	
4	Gannett		30	16.30		56.82		07	19.48	
12	Willard............		35	42.55		56.81		12	45.74	
5	Gannett	12	09	34.50		56.75		46	37.75	
13	Willard............		10	05.60		56.75		47	08.85	
	Dean		14	02.30		56.74		51	05.56	First inner contact was well observed.—G. W. D.
14	Willard............		14	03.70		56.74		51	06.96	
	Close of No. 14 (?)....		16	01.60		56.74		53	04.86	
	Unknown...........		16	07.40	....			53	10.66	
	....do		16	17.80		56.74		53	21.06	
15	Willard............		37	37.30		56.70	12	14	40.60	

APPENDIX No. 14.

REPORT OF OBSERVATION OF THE ECLIPSE OF THE SUN OF DECEMBER 22, 1870, BY DR. C. H. F. PETERS, DIRECTOR OF THE LITCHFIELD OBSERVATORY OF HAMILTON COLLEGE.

DEAR SIR: I have the honor to report upon my participation in the observations of the solar eclipse of 22d December, 1870. When, on being appointed a member of the United States Eclipse Expedition to the Mediterranean, I received the gratifying order to accompany the party that, under your personal leadership, was to be stationed in Sicily, I beheld that, besides contributing my share in the astronomical observations, the particular duty came necessarily to me to bring to bear what knowledge of the country, acquired there by a longer sojourn in former years, might be furthering the purpose of the expedition. It is consoling to me that while, in the former, the scientific investigation, by a freak of the weather only a very partial success fell to my lot, for the rest, my company at least indirectly has been, as I hope, of some usefulness. This, however, for a great part, is owing to the characteristic hospitality and readiness to assist of the citizens of Catania. The names of some of the gentlemen who thus have been of special help to us I shall take the pleasure to mention below.

In the preliminary preparations at home I directed my attention to fit my apparatus with the purpose to permit ease and effectiveness for investigating the solar appendages by direct vision. The eclipse of August, 1869, as observed by myself and the members of my party at Des Moines, Iowa, had intimated so clearly a certain structural arrangement, both in protuberances and in corona, that a closer scrutiny of these phenomena seemed to me particularly desirable. I had at my position an excellent telescope of Steinheil, of four inches aperture, five feet focal length, the gift of Mr. Litchfield on occasion of the preceding eclipse. Its object-glass is of exquisite perfection; it has powers ranging from 40 to 300, and is equatorially mounted, with setting-circles and tangent-screw for right-ascensional motion. I had now made, in addition, (by Mr. Chubbuck, of Utica,) a slide, which holds simultaneously three of the eye-pieces, so that, by the touch a spring, the power may be changed from the lowest to the highest almost without loss of time and without fear of deranging the position of the telescope. Thus, when all the three eye-pieces are adjusted to focus, and an object is seen near the center of field through the lowest power, in less than a second the highest magnifying-power may be brought to bear upon it. The consideration that nebulæ and gaseous bodies like comets usually reveal their various features only when viewed and examined under varied proportions between light and power, led me to expect much of the described arrangement in scrutinizing the luminous appendages of the sun.

Moreover, near to and at the side of the ordinary small seeker carried by the tube, (magnifying about nine times,) I had attached one of those beautiful little instruments called "hand comet-seekers" by Steinheil. The one in my possession, only six inches long, magnifying two and a half times, with an aperture of one inch, has a field rather more than 17°, which enables the observer to take in at one glance the whole of the eclipse-phenomena, even to the remotest rays of the corona.

These together, therefore, may be said to represent, upon one and the same equatorial stand, five separate telescopes, differing in power and extension of field. The small seeker alone had a sun-glass; a wedge of neutral tint could be applied to either of the three eye-pieces of the large tube for graduating the light according to circumstances.

The instruments were packed in four boxes, and went, with the other instruments of the expedition, from Liverpool by sea directly to Messina. As it was your wish that I might be early in Sicily to reconnoiter for the observing-stations, I left Clinton on October 29, and arrived at Liverpool on November 14. Then, after a few days' sojourn in London, where we conferred with

Mr. Lockyer and some of the other English observers, by the way of Southampton, Gibraltar, and Malta, I reached Catania on December 7. Here I had the pleasure of meeting Mr. Charles A. Schott, already arrived two days before; also the Italian observers were already on the spot, centered at Angosta, and Professor Cacciatore, director of the observatory of Palermo, and vice-president of the Italian commission, directed a greeting dispatch of welcome to the Americans on Sicilian soil, which was duly responded to in Mr. Schott's and my name.

The following days were spent in looking at localities in the neighborhood of Catania, where the instruments of the various observers might be established, and I extended my reconnoitering trips over the slope of Mount Etna, and as far as Lentini and Carlentini. The zone of totality (as indicated also on the accompanying sketch) covered the whole southeast corner of the island of Sicily, including Cape Passaro, its northern limit intersecting the east shore of the island a few miles north of Taormina. It would have been of some interest if observers could have been stationed along the whole coast from Cape Passaro to Taormina, forming a line nearly at right angle to the path of the moon's shadow, and extending nearly across the whole width of it. Various circumstances, however, combined to prevent this scheme. Transportation, especially in the southern part of the island, is still very difficult, no carriage-road leading to Cape Passaro or its surroundings. Already, for this reason, the more ponderous instruments were necessarily restricted to the neighborhood of the larger towns. Moreover, the photographic and spectroscopic apparatus, besides needing a longer accurate preparation and adjustment in a firm position, were to be stationed not too far from the central line of totality, in order not to have too much curtailed the duration of two minutes in maximum. Fortunately, there were the three towns of Angosta, situated very near the central line, and Syracuse and Catania, about half way from it to the southern and northern limits respectively. The Italian astronomers had established themselves at Angosta; at Syracuse was the party of the United States Naval Observatory; for our photographers, and as headquarters for time and latitude observations, the best opportunity was presented at Catania.

There remained the distribution of the portable telescopes for direct eye-observation, which, supplementing the spectroscopic investigation in this eclipse, it was hoped would essentially contribute to solve the enigma of the nature of the corona. Between English and Americans now united, there were on hand, prepared for this purpose, observers sufficient in number to attack the corona from stations situated more or less eccentrically across the whole zone of totality. A still more promising arrangement, however, seemed to be offered spontaneously by Mount Etna. Usually, this mountain becomes snow-covered, and ceases to be accessible beyond the "regione nemorosa" in the latter half of October. This year the mountain was quite exceptionally free of snow. I saw distinctly the Casa Inglese entirely free only two days before the eclipse. It seemed as if thus the mountain itself invited the observers. The idea of having a series of stations with lesser and lesser densities of atmosphere (at the Casa Inglese the barometric pressure is only 540^{mm}, or two-thirds of that on the level of the sea) was too tempting; it would put decisively at rest the question whether the corona is simply an effect of our atmosphere. Consequently, a number of forces were dispatched for the slope of Mount Etna, arranged, so to say, upon the third co-ordinate—that of altitude. The highest point was reached by General Abbot, United States Engineers.

I have tried to represent in one view upon the accompanying sketch the final disposition of all the stations in Sicily as they were occupied by parties of the various nations co-operating. There may be placed on record yet, as near as I could ascertain, the names of the observers of each station.

I. Italians:

Angosta.—Cacciatore, Secchi, Donati, Blaserna, Agnello, De Lisa, Photographer Tagliarini.
Terra Nuova.—P. Tacchini, Lorenzoni, Legnazzi, Nobile, A. Tacchini, Diamilla Müller, Serra.
Slope of Mount Etna, (in about 8,000 *feet elevation.)*—Count Schio.

II. Americans:

Catania, (Garden of the Benedictines.)—Schott, Lane, Photographers Fitz, Chapman, Burgess.

Catania, (casino di St. Giuliano, elevation about 500 *feet.)*—B. Peirce, Superintendent, Charles Peirce, with Mrs. C. Peirce and Mrs. Parsons.

Carlentini.—Watson.

Monte Rossi, (elevation 3,120 *feet.)*—Peters, Eimbeck.

Slope of Mount Etna, (elevation 8,000 *feet.)*—General Abbot.

Syracuse.—The party of the United States Naval Observatory, Harkness, Hall, Eastman, and Mrs. Eastman.

III. ENGLISH:

Catania, (Garden of the Benedictines.)—N. Lockyer and Mrs. Lockyer, Seabroke, Cumming, Thorpe, Pedlar.

Angosta.—Adams, Burton, Clifford.

Near Villasmunda.—Ranyard, Samuelson, Brett.

Syracuse.—Brothers, Fryer, Griffiths.

Slope of Mount Etna, (Casa Terentina del Bosco, elevation 5,500 *feet.)*—Roscoe, Bowen, Harris, Darwin, Photographer Dr. Vogel, and Professor Silvestri of Catinia.

I come now to report on my part taken in observing the eclipse. With your consent I located my station on the western top of the Monte Rossi di Nicolosi, on the identical spot that had formed a point in the triangulation of Mount Etna made years ago by Baron Sartorius von Waltershausen and myself. The immortal Gauss himself, for his own pleasure, in a leisure hour, had submitted our triangles to his theory of compensation, and derived the most probable values for the signal on Monte Rossi:

$$-12776^{m}.051 \text{ north};$$
$$+6090^{m}.214 \text{ west};$$

counted from center of dome of the monastery of S. Nicola de' PP. Benedettini at Catania.

The geographical position of the latter place was ascertained by myself at the time, and has been redetermined by Mr. Schott on this occasion. The co-ordinates stated, when reduced into arc by means of Bessel's constants for the dimensions of the earth, will be—

$$6' \, 54''.45 \text{ north, and}$$
$$4' \, 8''.18 = 16^{s}.545 \text{ west of Catania};$$

and the elevation above the level of the sea we had determined trigonometrically at $948^{m}.7$.

You allowed me the assistance of Mr. Eimbeck. We started from Catania early on December 21, and completed the last preparations at Nicolosi that same afternoon; in which was of much use to us the young Doctor Bonanno, a native of the place, who also gave us his company upon the mountain the following day. Nicolosi is the last village on the southern slope of Mount Etna, 707^{m} above the sea, whence to the top of Monte Rossi is about an hour's walk.

Mr. Eimbeck was provided with one of the Munich portable spy-glasses, (12 lines aperture, magnifying from five to six times,) and I used the telescope described above. Mr. Schott had given us one of the Coast Survey chronometers, (Sid. Chron. Hutton, No. 208,) which was compared at Catania immediately before and after the journey. Besides, in order to be independent of any change of rate the chronometer might suffer by transportation, it had been concerted between Mr. Schott and myself to exchange signals by flashes of light, as a sort of heliotropes, using a couple of common mirrors that were brought to reflect the sun's rays in the direction of our stations. The moments when the light was withdrawn by a sudden turn of the mirror were noted with our respective chronometers. The signals were given before the beginning of the eclipse. Though but few of them, as was found afterward, could be made use of, either on account of indistinctness or from uncertainty of identifying them or from want of correspondency, still, the precaution of a check proved of some value, as the rate of the chronometer of Monte Rossi really appears to have changed considerably.

The weather on the day of December 21 was fair, and promised a good success. In the afternoon, however, I was forewarned by my old friend, the venerable Dr. Giuseppe Gemellaro, the "guardian" of Mount Etna at Nicolosi, that the barometer was going down; and, indeed, toward evening clouds arose, the sky became overcast, and later it began to rain, storming during the night pretty heavily. The rain lasted still at 7 o'clock in the morning of the momentous day; but then it ceased, the clouds broke, the veil lifted itself, and Mount Etna stood there in glorious and

beautiful clearness—snow-clad now, as if it had exchanged its dark hue of yesterday for a white holiday dress to honor the occasion. Quickly the mules, that had been kept in readiness with their pack-saddles, were loaded with the instruments, and gay-hearted we ascended to the top of Monte Rossi; for the weather seemed to have exhausted its wrath, and everything went on promising beyond all expectations. Signals for time were exchanged with Mr. Schott, the sun shining bright through the purest sky. By the village-carpenter, whom I had hired to assist, the parallactic top-piece of the telescope was mounted on a wooden base. The axis I adjusted approximately to the meridian, pointing it by the eye a little east of the Montagnuola, (an eruption-crater of 1763,) where from Waltershausen's chart I judged the meridian of Monte Rossi to pass.

The beginning of the eclipse was noted at—

$18^h\ 40^m\ 50^s$ chronometer-time;
$=18\ \ 39\ \ 53.9$ sidereal time;
$=\ 0\ \ 36\ \ 36.4$ mean time.

I am not sure, however, but that this was too late by some seconds; for the strong undulations which agitated the sun's limb may have concealed the real indentation of the moon upon the disk several seconds before I became aware of it. Besides, though the instrument was placed on the side sheltered by the top, it was not quite exempt from being shaken by currents of wind, to which that rather isolated peak is freely exposed. Mr. Eimbeck, with his smaller glass, observed the first contact at—

$18^h\ 40^m\ 52^s.5$ chronometer-time;
$=18\ \ 39\ \ 56.4$ sidereal time;
$=\ 0\ \ 36\ \ 38.9$ mean time;

and estimates that the true contact may have occurred about two or three seconds earlier.

During the partial eclipse, while smaller and smaller was growing the solar crescent, the moon's edge was always very steady and sharply defined. A great many people by and by had gathered around us—one might almost say the whole male population of Nicolosi had climbed the mountain. They were most orderly and respectful, however, and remained modestly at the distance, beyond the limits marked off by two American flags; so that there was hardly need of the guard of three gensdarmes, whom the *intendente* of the province of Catania kindly had had the foresight to order to accompany us.

Meanwhile a very suspicious-looking cloud came creeping around the northwest corner along the slope of Mount Etna, drawing alarmingly nearer and nearer in proportion as the sun's sickle became narrower. It was a quarter of an hour yet until totality; already I saw our companions at the Terentina enveloped in dense mist; five minutes later, and with a gush of wind, down came upon us rain-drops with hail and sleet, so that for protecting the object-glass I had to put the cap on. This hail-storm had the effect of driving the crowd of people precipitously down-hill toward home. The minute for the commencement of total eclipse was fast approaching; those were moments of great anxiety. There is hope yet! I see the end of the cloud; there is clear sky below it, on the horizon in the northwest. How slow the cloud moves! but the clear spot is widening. "Time is up!" But, perhaps, there is an error in the computation, for the darkness is no greater yet than any thick dense cloud alone would produce; we can read the chronometer all the time with the greatest ease. Throwing our eyes again upon that clear opening in the northwest, we behold it considerably enlarged, but shining now with a peculiar sombre, greenish-gray tint, that casts over the whole landscape a certain awe. It is the tinge produced by the shadow. There can be no doubt the total eclipse has begun. The cloudy vail is rapidly gliding away; its following edge is approaching the place where the star of the day must stand. We are ready with our telescopes. Now, on the cloudy rim, it brightens. "Venus!" my assistant called out. Alas! it was not Venus, but a small crescent of the re-appearing sun; my more powerful magnifying-glass at the same instant revealed it too clearly. Totality was passed. With a disappointment, made only more painful by the thought that three minutes earlier would have sufficed for witnessing the entire phenomenon in a cloudless sky, I resigned myself to dismount the instrument. Mr. Eimbeck noted yet the end of the eclipse at—

$21^h\ 24^m\ 4^s.0$ chronometer-time;
$=21\ \ 23\ \ 7.5$ sidereal time;
$=\ 3\ \ 19\ 23.2$ mean time.

The correction and rate of chronometer have been adopted as computed by Mr. Schott.

At Nicolosi we joined our companions from the higher stations on Mount Etna, who, equally unfortunate, moreover had had to sustain a greater degree of inclemency of the weather. Late in the evening we reached Catania.

It may not seem amiss here to touch shortly upon the hypothesis advanced by some at the time, that the cloud interfering with our observations in Sicily just at the critical moment, coming and passing by almost as rapidly as the obscuration of the sun, possibly might have been produced by the eclipse itself. The moon, it was argued, interposing herself before the sun, hence shutting off the solar heat, effected a cooling of the particles of air, and condensed the vapors in the line of the shadow. Indeed, if we incline to adopt the explanation advanced by a distinguished physicist of the origin of the solar spots, and in particular of the formation of the nuclei of the same, we might here find an analogon. But if such was the case, if an eclipse was capable of producing its own cloud, why is it that a total eclipse has ever been seen at all? In the present instance, the data are at hand for subverting that hypothesis. The various series of meteorological observations since published show unmistakably that the atmospheric pressure over almost the entire basin of the Mediterranean began to diminish already on the day before the eclipse, the barometer thereupon continuing to fall steadily. The cloudy and stormy weather experienced, therefore, was preparing long before the eclipse began, and we can see nothing extraordinary in their coincidence. The same may be said likewise in regard to the variation of the magnetic needle observed by the Italian party at Terra Nuova.

In concluding this report I think it my duty to record the names of the gentlemen who, with so much kindness and disinterestedness, furthered our undertaking in Sicily, and who therefore have a just claim upon science for gratitude. In the first place, among these I must mention the Marquis di San Giuliano, who, besides endeavoring in many ways to make the sojourn at Catania personally pleasant to the members of the expedition, offered liberally, if desired as observing-stations, the comfort of his villas at Viagrande, at Villasmunda, and at the Carcarazzi above Catania. Of these, the last one now has a place in science through the observations made there by the Superintendent's party. The aid of Mr. A. Peratoner, consular agent of the United States at Catania, was frequently called into requisition, too often perhaps in quite trivial matters. He gave his assistance assiduously; for this and for his other acts of kindness, a grateful memory remains with every one of us. Prof. O. Silvestri, whose zeal and interest in the good success of the observations may be inferred from his participating in the hardships of one of the Etna parties, gave important assistance to our photographers by the use of his chemical laboratory. To my tried friend, Prof. G. Zurria, I owe much valuable information about localities; he contributed to Professor Watson's good success by procuring a letter of introduction to the hospitable Messrs. Modica, at Carlentini. Many other gentlemen aided us in various ways, to name all of whom singly would be impossible. Our thanks are due for a standing invitation to visit the rooms of the Casino and of the Gabinetto letterario Gioeni. The *cindario* of the city of Catania, Signor Marchese di Casalotto, to whose authority the abolished convent S. Nicola of the Benedictines now is subject, was always anxious with prompt orders to satisfy our wishes. From the Sicilian custom-house officers we experienced the greatest politeness. The Italian government, as is known to you, had given direction for the undisturbed entry of our instrument-boxes. The same liberal spirit pervaded the *intendente* of the province in providing that we might do our work unmolested. And, in thanking you, dear sir, for having offered me the occasion of seeing again a country that I had once seen sobbing under political absolutism, I may not omit to mention—if it does not seem improper in this place to speak of one's sentiments—how, in looking down from the top of Monte Rossi over the plains, I could not help feeling with joy that we, from the land of freedom, had come to a country not only blessed by nature in every respect, but, now, free too!

Yours, very respectfully and truly,

C. H. F. PETERS.

Prof. BENJAMIN PEIRCE,

Superintendent U. S. Coast Survey, Chief of U. S. Eclipse Expedition.

APPENDIX No. 15.

ON THE ADAPTATION OF TRIANGULATIONS TO THE VARIOUS CONDITIONS OF CONFIGURATION AND CHARACTER OF THE SURFACE OF COUNTRY AND OTHER CAUSES.—REPORT TO PROF. BENJAMIN PEIRCE, SUPERINTENDENT, FEBRUARY 20, 1873, BY CHARLES A. SCHOTT, ASSISTANT UNITED STATES COAST SURVEY.

Whatever may be the design of any geodetic operation, whether to survey a portion of the entire surface of a country, or only its coast or boundaries; or whether its purpose is to measure arcs of the meridian, of the parallel, or inclinations in any azimuth, (as a contribution to the data for ascertaining the figure of the earth,) it must be based upon a triangulation, the greater or less complexity of which will depend chiefly and necessarily on the hypsometric features of the country and on the nature of its surface.

The adaptation of a triangulation to these various conditions, and, at the same time, paying proper attention to accuracy, economy, and rapidity of execution, requires special consideration in each case. Before discussing these conditions more closely, however, it will be advantageous to refer briefly to the different kinds of triangulation. For the sake of convenience they have been classified under the heads primary, secondary, and tertiary. These may be defined as follows:

Primary triangulation is characterized by the maximum development which the configuration of the country admits of. Its sides, therefore, may frequently exceed 160 kilometers (about 100 statute-miles) in length, while they rarely descend below 30 kilometers (about 19 miles) for slightly undulating surfaces, and never below 20 or 25 kilometers (about 12 or 15 miles) in perfectly level countries. Primary work is executed with the greatest possible accuracy, and the uncertainty in its resulting linear measures should be less than $\frac{1}{60000}$ of the length, (which represents an error of about one inch to the mile.) To reach a higher standard of excellence, as for instance $\frac{1}{200000}$, or even a smaller fraction, requires the application of the most refined means at our disposal.

Tertiary triangulation, which should be accommodated to the wants of the topographer and the hydrographer, practically brings its sides down to the minimum length demanded for plane-table work on a large scale, (about $\frac{1}{5000}$ to $\frac{1}{10000}$;) they may be as short as $1\frac{1}{2}$ or $2\frac{1}{2}$ kilometers, (1 or $1\frac{1}{2}$ miles;) ordinarily the sides vary between 5 and 8 kilometers, (about 3 and 5 miles.) In this work an uncertainty of $\frac{1}{5000}$ in the resulting distances is not commonly considered excessive.

Secondary, or the intermediate, triangulation simply effects a connection between the above extremes.

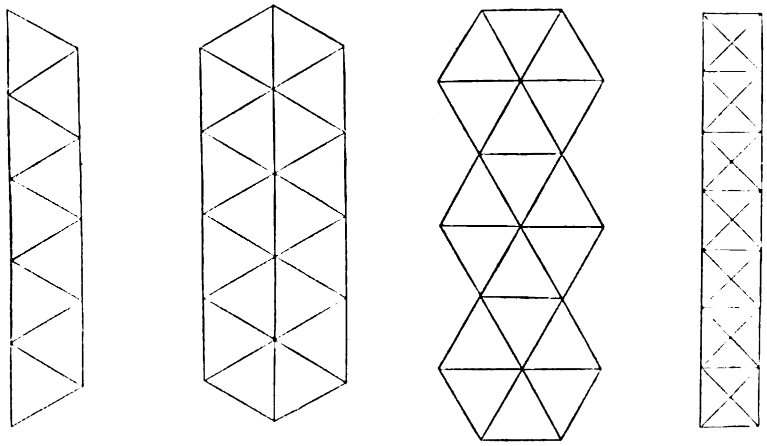
Any one of these classes of triangulation may form a distinct or separate series, and the primary class always does so; or the secondary and tertiary may cover the same area as the primary, in which case they are directly checked by it. Any series of triangles (or combinations of triangles) designed to connect two distant positions, such as opposite boundaries, terminal points of an arc, or separate branches of a triangulation—for instance, those running along a coast or up a river—should be constructed as a *main* or *principal* series, along which distances and azimuths are carried forward in the most accurate (relatively) and expeditious manner. The termination of such branches is usually strengthened by the measure of a check-base and of an astronomical azimuth.

If a country is to be covered with a net-work of triangles, (or combination of triangles,) the question will arise how to arrange these in the most effective manner; we may, for instance, gradually cover the whole area with contiguous triangles, (and combinations,) all measured with equal care, taking advantage of the surface-irregularities to expand to the greatest scale practicable.

This system has the disadvantage of leading rapidly into an unmanageable number of conditions to be satisfied in the adjustment of the parts, and this necessitates the parceling out of the net-work into certain connected, yet in a measure arbitrary, figures, not too extensive to be separately adjustable; and the further gradual adjustment necessary to remove the discrepancies along the junction or boundary-lines of the contiguous figures. On the other hand, we may first surround the surface by a connected series of triangulation to serve as a *frame-work* in which other primary *traverse* series may be inserted, and after adjusting this figure* may introduce a second system of parallel series of triangulation intersected by others (best at right angles to the former) in order to cut or subdivide the interjacent (rectangularly-shaped) areas left by the preceding system, and to continue such subdivision of areas until the whole surface is covered sufficiently with trigonometrical stations. In adjusting any system, the preceding one upon which it depends is taken as not subject to any further correction. As in the first method, every advantage must be taken of the natural facilities offered by the ground, and sometimes diagonal or tie series may be more advantageous than rectangular connections. For the survey of a coast-line or boundary we may run a main series parallel to the general direction of the lines, and select for it the most suitable ground; lateral branches at intervals will connect the main series with the coast or boundary. A series of triangles following a mountain-range, or axis of elevation, may advantageously rest with one side on the crest or slope and with the other on the plane at the foot of the elevation; but the most favorable case is that of a valley, of the proper width in comparison with the relative elevations, and a well-shaped triangulation resting on the crest of the ranges or hills on each side. The most difficult ground to traverse for primary triangulation are heavily-wooded parallel ridges, closely packed, and of nearly equal height, running at right angles to the direction of the triangulation.

The general direction and character of a triangulation having been decided on, we have next to consider its composition. A series may be formed of a single string of triangles, of a double string, or hexagons, (or of other polygonal figures,) of quadrilaterals, or it may be composed of any combination of triangles. Since any of these systems may find its proper application, according to circumstances, a somewhat closer examination of their relative merits seems to be demanded.

The plainest form is that of a single string of equilateral triangles, and is the one to be adopted when economy and rapidity of execution are the first requisites; the hexagons (connected either axially or hinged) commend themselves when a large area is to be covered; and a third form, that of quadrilaterals, offers itself as the one possessing greatest strength or admitting of the greatest accuracy. The relative value of the usually mixed systems may be judged from their characteristics when compared with the three simple systems just mentioned.



If we take for the unit of length the maximum distance at which it is advisable to place two stations for observation, in conformity to the nature of the ground, the efficiency of the instruments,

* In general, to close any circuit, four equations must be satisfied, which may be considered as arising from the following causes: first, the *length* of the connecting side must be the same, whether we arrive at it from one direction or from the opposite one; secondly, the direction or *azimuth* of this line must be the same; thirdly and fourthly, the *latitude* and the *longitude* of one of the end-points of the line must come out the same respectively. In the case of primary trav rses, the circuits are mutually dependent, and require to be treated collectively.

and means at our disposal, we may estimate the relative value of the three systems under various aspect by examining their results for a given equal length. Since nine equilateral triangles, reaching to five units, carry us nearly as far as three hexagons, ($3\sqrt{3} = 5.20$ nearly,) and slightly surpass seven quadrilaterals, having diagonals of unit-length, ($7\sqrt{\frac{1}{2}} = 4.95$ nearly,) a length of five may be taken as a convenient measure of comparison for efficiency.

The following table exhibits such numbers as are required for comparison:

System.	Composition.	Range.	No. of stations.	Total length of sides.	Area.	No. of conditions.
I.	Triangles, equilateral..........	5	11	19	4.5	9
II.	Hexagons, hinged...............	5.2	17	34	9	21
III.	Quadrilaterals, squares..........	4.95	16	29.6	3.5	28

With respect to the *number of stations* to be built up or occupied, system I is the most favorable, and II and III are almost equal; with respect to *length of sides*, of special importance when lines have to be cut through heavy woods or brush, system I is least unfavorable and system III slightly better than system II; with respect to *area* covered, system II is by far the most advantageous, the other systems showing but one-half and less, than the hexagonal; this system appears, therefore, best adapted when spread of triangulation is most desirable; but if axially arranged, the hexagon sare less favorably disposed, being narrower and lacking the salient points of the ordinary connection. With respect to the number of geometrical conditions, * system III is the most favorable, and, with these conditions satisfied, will consequently be capable of giving the greatest relative accuracy. Strength, however, is here gained at the expense of area. Generally, for comparatively flat surfaces, the hexagonal, and for countries traversed by mountain-ranges, the quadrilateral system, may be employed with advantage, while for rapidity of work and cheapness a string of single triangles is unsurpassed; yet, however complicated, mixed, stretched, or distorted the actual scheme may be, we always keep in view that the greatest care is to be given to the measures connected with this main series, while at the same time due attention is paid to the secondary objects, thus saving re-occupation of the primary stations in connection with subordinate operations.†

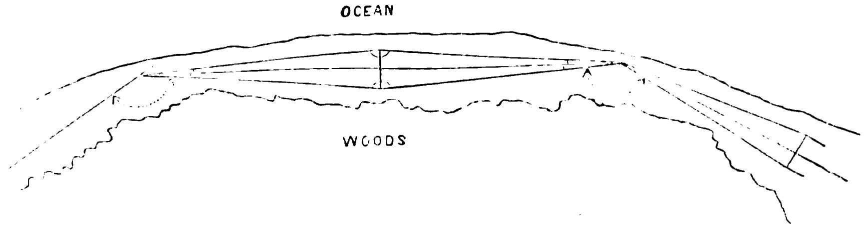
Two other systems of survey may here be noticed, designed to meet the special difficulty where want of breadth makes the ordinary methods inapplicable. Their use applies to the case of a narrow sea-beach fringed with woods which it may be undesirable or impracticable to penetrate. The system first to be described, and which has been successfully employed on certain parts of our southern coast, consists in actually measuring a series of connected lines, as in base-measures, either with rods or wires, the termini of each line being at the *maximum* distance admitting of intervisibility, and in measuring the angle or difference of azimuths at each junction. Each one of such lines may be composed of a number of broken lines, but the parts are referred to the single straight line at which angles are measured. Owing to the expense of line-measures, the application of this method is limited. In the second auxiliary method, due to Struve,‡ this objection is met by the substitution of a number of small base-lines—that is, one for each long line—and located so as to be at right angles and bisect each other as nearly as may be, thus forming a series of greatly drawn-out quadrilaterals. The horizontal angles are then measured at the ends of the little base, also at the terminal points of the long line, the length of which thus becomes known. The base may be from one hundred to several hundred meters in length, and that of the long line or diagonal

* If in system I, n = number of stations, not less than 3, then number of conditions $= n - 2$; for system II, n = number of stations, not less than 7, and forming complete hexagons, number of conditions $= \frac{7n - 14}{5}$; for system III, n = number of stations, not less than 4, and forming complete quadrilaterals, number of conditions $= 2n - 4$.

† In the measures of directions at a primary station, should a line offer special difficulties from its great length or want of transparency of the atmosphere, the expedient may be adopted of erecting a signal at a moderate distance in the direction and measuring *micrometrically* the angular difference of the two objects under favorable circumstances. The use of so-called referring-objects is not recommended, as it unnecessarily increases by one the number of directions to be fixed.

‡ Astronomische Nachrichten, No. 336, (1837.)

may be from ten to fifteen times that of the base. Azimuthal differences are measured as before, and the computation of the latitude and longitude of the points is effected as in ordinary triangulation. This last expedient may be of occasional help when operating on shores obstructed by watercourses, lagoons, or swamps. Islands or rocks, lying off shore at no great distance, frequently supply the means of carrying a subordinate series of triangulation along shore.



The following remarks on the length of primary base-lines, and on their mutual distances, may find a proper place at the conclusion of this paper. In the present state of practical geodesy, primary base-lines of a length of about 10 or 11 kilometers (nearly $6\frac{1}{2}$ statute-miles) represent a fair average.* The intervening triangulation varies greatly in length. This depends principally on the size of the triangles and on the accuracy of the measures; yet ordinarily any two primary base-lines may be found separated by a distance from forty to eighty or even one hundred times the average length of a base; that is, from about 400 to 900 kilometers, (about 250 to 560 miles.) Tertiary base-lines are usually between $\frac{3}{4}$ and $1\frac{1}{2}$ kilometers (about $\frac{1}{2}$ and $1\frac{1}{2}$ statute-miles) in length, and in a chain of tertiary triangulation not otherwise checked may follow at intervals of about 40 or 70 kilometers, (nearly 25 or 44 miles.)

The properties of a base-line, or, more strictly, of its theoretical equivalent, have been but little investigated, and a few remarks respecting its definition may not here be deemed out of place.

A base-measure may be conceived to proceed from the starting-point A, on the surface of a spheroid, in a plane containing both its vertical and the terminal point B, and to be continued so that at any point of it its linear element be situated in the plane passing through its normal and through the termini A and B. A curve so traced will in general be of double curvature, and lie between (excepting the case of A and B lying on the same parallel) the two plane elliptic arcs *a* and *b*, which result, the first from the intersection of the spheroid by the vertical plane containing the normal of A and the point B; the second from the intersection of the plane containing the normal of B and the point A. The element of the curve at A will necessarily coincide with the arc *a*, and at B with the arc *b*, and the curve will be similarly related to these arcs; that is, the same curve will be traced out whether we start from A toward B or from B toward A. It has, from its definition, the property that for any point in it the forward and backward azimuths differ 180°; and since the terminal points A and B lie in the plane of its normal, the azimuthal plane must contain the chord or straight line joining A and B. The curve will also be marked out by the junction of the foot-points of normals let fall from every point of the chord to the surface of the spheroid. The curve, being situated apparently in a direct line between the terminal points, may be distinguished by the name "direction-line," the name base-line having been given to the line actually measured, and which is composed of a number of straight lines. Doctor Bremiker† pertinently remarks that the name "geodetic line" should properly have been given to this curve, since it actually enters into the two fundamental geodetic operations, viz, the linear and angular measures; the latter on account of the tangency of the curve to the plane of the arc *a* in which the line of collimation of a theodolite stationed at A is situated. The name "geodetic line," however, is already appropriated for the shortest line (and which does not always lie between the arcs *a* and *b*) that can be drawn between two points on the surface of the spheroid, and which differs in direction from the curve here considered.

* Thirteen lines of the Coast Survey average 6.2 statute-miles; ten of the Indian trigonometrical survey, 6.6; and seven of the English ordnance survey, 5.9 miles.

† Studien über höhere Geodäsie, Berlin, 1869. The name "field-line" is suggested by Doctor Bremiker, who gives the equation to the curve on page 66 of his pamphlet.

APPENDIX No. 16.

DESCRIPTION OF A NEW FORM OF MERCURIAL HORIZON, IN WHICH VIBRATIONS ARE SPEEDILY EXTINGUISHED, BY J. HOMER LANE, OF WASHINGTON, D. C.

In the operations of the Office of Weights and Measures, occasion has arisen for the use of the collimating mercurial horizon. This is not the place to report upon the special use to be made of it in this office; but an improvement has been made in the mercurial horizon itself, which is likely to prove valuable for the purposes of practical astronomy. At the united request, therefore, of the Superintendent and Assistant Superintendent of the Office of Weights and Measures, I here communicate a description of it for the American Association.

The improvement consists simply in reducing the depth of mercury in the trough to a very small quantity. This extinguishes the oscillations or waves, which otherwise, upon the slightest causes, disturb the reflection when the horizon is used with a telescope. The least depth with which pure mercury will overflow a horizontal non-metallic plane surface is a little over one-eighth of an inch. If, however, the mercurial lake be left of this full depth, at and near its boundary, with room for the capillary curve, then, inside of this encircling space, the bottom of the trough may rise as near as we please to the level surface of the liquid.

The first trough which we have tried on this plan is the only one that has been used prior to this current week of the present meeting of the association. It was a wooden trough, formed in the lathe, with a horizontal circular plane or plateau, of six inches diameter, on a level something like one-sixth of an inch higher than the bottom of the deepest part of a margin of two inches wide all around it. The deepest part of this depressed margin was in the middle of its width, the object being to soften the horizontal shocks which may be communicated to the mercury; but I think this is of little importance or value, since the capillary boundary will still be the origin of ripples produced by vertical shocks. The ripples of the surface of a mass of mercury produced by tremors are observed, in fact, to have their origin mainly at the borders; and this is the reason why the central flat plateau of the trough was made so large as six inches in diameter, while the clear aperture of the telescope collimated over it was only from two to two and one-half inches in diameter.

In preparing the horizon, the trough was first set very nearly horizontal by a spirit-level. A sufficient quantity of mercury was then poured in to overflow the whole bottom of the trough, at least with the aid of a little displacement. The large excess of mercury was then drawn off through a small hole which had been made at the deepest part of the deepened margin, and closed by a little plug. The mercury was allowed to flow until the level of its surface sank to the indication of a gauge laid across the top of the trough, leaving a very thin layer only on the plateau. The effect of this artifice in curing the disturbance produced by tremors was charming and complete.

But to secure this effect, care must be taken that the depth of mercury on the plateau be reduced sufficiently. It is quite surprising to notice how small a depth is still sufficient to transmit across the plateau the little ripples that mar the sharpness of the reflection. I made no determination of the thickness used, but I think one-hundredth of an inch is small enough. It is easy, by gentle taps upon the trough as the mercury flows off, to notice when the ripples, with the diminishing depth, begin to grow sluggish, and when the point is reached at which they quickly die out on the plateau.

Although the depth is so small when this effect is thoroughly secured, it yet very greatly transcends the thickness of a mere bubble or film of capillarity, and, therefore, there is no room to anticipate that the surface of the plateau will have any influence upon the horizontality of the upper surface of the mercury. In point of fact, the horizon above described has been under the

severest telescopic test, and yet the irregularities of the plateau were not sufficiently copied by the mercurial surface to mar the definition of the object-glass. To the same purpose, I will state that on one occasion the trough was tilted slightly by pressure made on one side of it with a staff. Momentarily the mercurial surface tilted with the plateau by a large quantity, as seen in the telescope; but the changed inclination of the plateau being maintained by continuance of the pressure, the mercurial surface soon settled, upon the inclined plateau, into its original position of horizontality, any difference being at all events quite insensible in this imperfect experiment. We shall now, however, have opportunity to put this question to a more rigorous test with a cast-iron trough, which has just been completed, and which, by the kindness of Professor Hilgard, I am permitted to submit, through him, to the inspection of the association.

This iron trough has a circular plateau of about six inches in diameter. The deepened margin around the plateau increases the diameter to six and one-half inches. This deepened margin, at its outer boundary, is extended downward all around in a very narrow annular passage, to the depth of three-fourths of an inch below the level of the plateau, where it opens horizontally outward into an annular reservoir, one-half inch wide, which surrounds the plateau, and rises a fraction of an inch above it. This annular reservoir is closed air-tight above, but is provided with a screw-valve to control the passage of air. When this screw-valve is opened, and air forced in through a flexible tube with the mouth or otherwise, the mercury in the annular reservoir is forced through the annular passage and flows over the plateau, and is sufficient in quantity to flood it throughout. The continuity of surface over the plateau having been secured, the mercury is allowed to flow back into the annular reservoir; and the whole quantity of mercury may be adjusted so as to settle to the depth that is desired on the plateau. The rapidity of this return-flow of the mercury may be controlled by checking the escape of air through the screw-valve. Should any accident cause the breaking of the film of mercury, the arrangement here described affords the means of its convenient and speedy renewal. The film will never break except by accident.

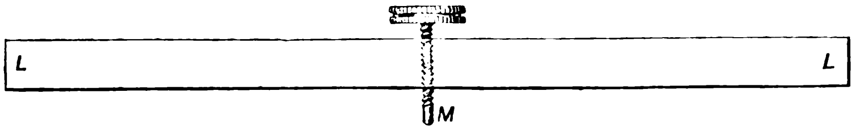
The screw-valve can also be used to suspend the return-flow until the trough, which is furnished with leveling-screws, can be leveled by the surface of the mercury.

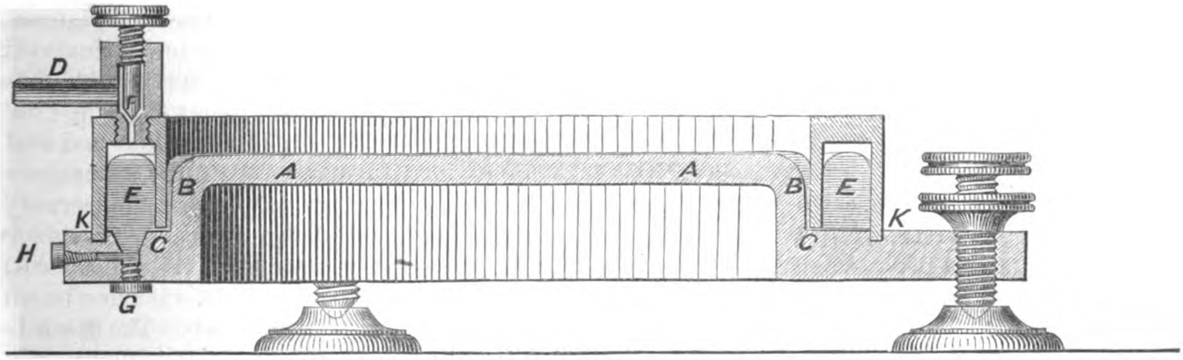
The plateau should be made of a material pervious to air, so as to allow of the escape through it of the small bubble of air which the mercury imprisons in completing its continuity at the first flooding. The bubble does indeed flatten out a good deal under the capillary curve, but the conditions of the curvature fix a definite limit to the diameter of the bubble, and so to the smallness of its depth. Accordingly, in experimenting with the cast-iron horizon described, it was found that the thin film frequently broke over this air-bubble. This drawback was not encountered in the use of the wooden horizon first made, although that had, I believe, been varnished. The remedy proposed, viz, the use of a material pervious to air, is more simple and satisfactory than any method which has occurred to me of making the completion of continuity take place off of the plateau. Though cast iron is, in a degree, porous, it is doubtful whether it can be made sufficiently pervious, though this may yet be tried by removing the outer film of the casting from the under surface as well as the upper, and avoiding all use of lacquer.

The objection to wood as the material of the plateau is the difficulty or trouble of conquering its variability of form. A plate of plaster of Paris can easily be substituted for the cast iron in that part which forms the plateau, and a little of the depressed border around it. Its comparative fragility will hardly be a serious objection in a fixed observatory. If plaster be the material chosen, the plaster plate would rest upon an annular shelf formed in the iron skeleton by the lathe, and may be cast in its place by inverting the iron skeleton upon a mold or former. The skeleton may be at a relatively low temperature at the moment of forming the plaster cast, or other means taken to guard against possible distortion by unequal expansion and contraction.

The accompanying wood-cut shows a vertical section through the center of the iron trough as it has been made. A A is the plateau, cut down around the border so as to leave space for the curve of capillarity, and for a considerable mass of mercury beneath this curve. The falling away of the plateau should begin at a distance of not less than four-tenths of an inch within the wall that confines the mercury. B C is the narrow annular passage through which, by forcing in air at the air-tube D, the mercury contained in the annular reservoir E may be driven until it floods the plateau. After the mercury has been drawn down again under check of the screw-valve F, this screw-valve must be left fully open in order to avoid all risk of confining the air in the upper part

of the reservoir. When it is necessary to remove the mercury from the trough, the last portions are drawn out at the screw-plug G. A much smaller screw-plug, H, may be used, when charging





the trough with mercury, to adjust the quantity of mercury which is to be kept in the trough, and which will fix the thickness of the film on the plateau. The piece in which the reservoir E is formed is fitted at K tight enough to retain the mercury, and it is advisable to make it take off for cleaning.

DIRECTIONS FOR SETTING UP AND USING THE HORIZON.

Place the trough upon a firm support. Level it by means of its three foot-screws, keeping these screws always secure from shake by means of their tightening-nuts. The level or want of level is ascertained by laying a spirit-level across the top of the trough along two diameters, and turning it end for end on each diameter. If, however, the trough has not been made with the plane of its top truly parallel to the plane of the plateau, it should be furnished with a spirit-level short enough to rest upon the plateau itself. But care must be taken to avoid abrasion of the plateau, especially if it be formed of plaster of paris. Across the top of the trough lay the straight bar L L, or gauge-bar, in which works, near its front surface, a vertical screw of steel, finished with a flat face at the lower end to form the gauge-point M. Take care that this gauge-point is at first set sufficiently high not to strike and injure the surface of the plateau. Then screw it downward till it will begin to pinch a thickness or two of common writing-paper laid upon the plateau. This adjustment being made, lay aside the gauge-bar for after use. Now pour upon the plateau as much thoroughly purified and clean mercury as is judged to be a slight overcharge, first taking care that the screw-valve F is fully open for the free passage of air. It will make its way through the annular passage B C into the annular reservoir E, driving before it the air of the reservoir, and none will be left on the plateau unless the charge of mercury is considerably too large. For otherwise, the rapid flow, with the screw-valve F fully open, will break the film over the edge of the plateau while yet the small excess of mercury remains accumulated upon the central parts. See that the whole plateau, together with the higher part of its depressed border, is free from particles of dust or dirt, going over it if necessary with a soft brush or a linen rag. Being provided with a piece of quarter-inch India-rubber tube three or four feet in length, slip one end of it upon the air-tube D, and apply the mouth to the other end. Force in air by the action of the muscles of the mouth, as in using a blowpipe. In this way a steadily-sustained pneumatic pressure is brought to bear upon the surface of the mercury in the reservoir E. Under this the mercury is forced back through B C, and overflows the plateau. Should the volume of mercury be somewhat largely deficient, it may happen that an insular patch of the plateau is left uncovered after the mercury has been all expelled from the reservoir E. More mercury must then be added; and if in making this addition fresh specks of dirt should come into contact with the plateau, the mercury is allowed to flow back

again into the reservoir. This flow being unchecked, the plateau will be left uncovered, unless the addition of mercury has been considerably too large. Otherwise, break the remaining layer of mercury with a piece of clean paper, when it will all retire, at least with a little aid from a soft brush, into the space formed by the depression of the plateau along its border. The uncovered plateau is then freed from the added specks of dirt, and the operation of flooding it with mercury is repeated as before. A certain volume will suffice to extinguish the insular patch of uncovered plateau, and form an unbroken lake of mercury. On then removing the mouth from the India-rubber tube, the lake of mercury will begin flowing freely back into the annular reservoir. But before the surface of the lake has had time, in its descent, to break upon the border of the elevated plateau, the screw-valve F is promptly closed. The flow of mercury from the lake into the annular reservoir then ceases, and the surface of the lake quickly becomes level throughout. The screw-valve F is then thrown open for a moment, and instantly closed again. The momentary renewal of the flow will produce a flow-wave, which will be seen by the eye to start at the border of the lake and end at its center. As rapidly as the level of the lake approximately renews itself, the momentary opening of the valve is repeated, until it is seen that no further flow takes place, and the mercury in lake and reservoir has settled to a common level. The valve is then left fully open. All this is quickly done after a little practice. If there be a deficiency of mercury, the film on the plateau will break before this stage is reached, and another addition of mercury must be made. If there be an excess of mercury, the film on the plateau is not only unbroken but may be too deep. The depth is ascertained by applying the gauge-bar with its previously-adjusted gauge-point M. Any excess of mercury is drawn off little by little at the screw-plug H till the film is reduced to the prescribed thickness shown by the gauge-point, or till the ripples produced by gentle taps made on the trough die sluggishly out without traveling half-way from border to center. After the charge of mercury has been once adjusted, nothing more is necessary than to keep it unchanged.

At the first flooding of the plateau it may happen that a speck of dirt is picked up by the mercury, borne on its surface, carried over the rolling and advancing edge of the moving fluid stratum, and so becomes buried beneath the mercury and in contact with the plateau. In this situation it will remain if not removed, and will, if thick enough, break the thin film of mercury to be formed.

If, in consequence of standing for a length of time unrenewed, the surface of the reflecting film becomes tarnished or dirty, a fresh clean surface can be reproduced in a minute or two by breaking the old film, brushing it from the plateau if time has caused adhesion,* and repeating the process above described for flooding the plateau and forming the film anew.

A caution of general application to any mercurial horizon may here be added. For accurate astronomical purposes care should be taken not to use the reflecting surface too near the edge. The deflection of the surface from horizontality by the force of capillarity may amount to 1″.0 at but little less than an inch from the extreme border of the mercurial lake, and increases very rapidly on any nearer approach to the border.

When for transportation it becomes necessary to remove the mercury from the trough, most of it can be poured out as from a plain trough, but a little will remain in the annular reservoir. This is readily removed at the screw-plug G. If care be taken to avoid loss of the mercury, and to store it in a bottle by itself, this will save the trouble of repeating the process of adjusting the quantity when the trough is recharged, and the weight of the charge may also be recorded on the trough.

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* Adhesion, if it takes place, cannot be supposed to affect the horizontality of the reflecting surface, since it does not interfere with the absolute fluidity of the stratum of mercury. It only takes effect at the surface of contact between the fluid stratum and the plateau.

APPENDIX No. 17.

GENERAL INDEX OF PROFESSIONAL AND SCIENTIFIC PAPERS CONTAINED IN THE UNITED STATES COAST SURVEY REPORTS FROM 1851 TO 1870.

KEY TO INDEX.

GEODESY:
- Latitude.
- Longitude and Time.
- Azimuth.
- Base-lines.
- Geographical Positions.

ASTRONOMY.

MATHEMATICS.

SURVEYING:
- Triangulation.
- Topography.
- Hydrography.
- Reconnaissances.

PHYSICAL HYDROGRAPHY.

TERRESTRIAL MAGNETISM.

DRAWING, ENGRAVING, AND ELECTROTYPING.

MISCELLANEOUS, TECHNICAL, AND OTHER SUBJECTS.

GEODESY.

LATITUDE.

Year.	Pages.	Title of papers.
1857	324-334	LATITUDE.—On the method of determination with the zenith-telescope.—C. A. Schott.—Principle of the method; determination of value of micrometer—examples; determination of value of level—example; correction for refraction—example; reduction to meridian—tables; selection of stars; sources of error in the determination of the value of micrometer; method of correcting value from the latitude-observations themselves; discussion of the results of observation—example.
1858	184-186	PERSONAL EQUATION.—A. D. Bache.—On the use of the zenith-telescope for determining latitude by Talcott's method—table showing results of observations for personal equation.
1866	72-85	LATITUDE BY THE ZENITH-TELESCOPE.—C. A. Schott.—1, general remarks on Talcott's method; 2, modification of instrument; 3, description; 4, adjustment; 5, selection of stars for observation; 6, directions for observing; 7, off the meridian; 8, general expression for the latitude; 9, determination of the value of a division of micrometer; 10, of level; 11, correction for differential refraction; 12, reduction to the meridian; 13, record of the observations; 14, reduction of the observations; 15, discussion of the results; 16, combination of the results by weight.—Examples to articles 9, 10, 13, and 14.—[Sketch 28.]
1865	160-165	REPORT ON THE LATITUDE OF CLOVERDON STATION IN CAMBRIDGE.—B. A. Gould.—Micrometer-values; reduction of star-observations—tables; discrepancies with uncorrected catalogue-places—table; resultant mean places of stars, &c.—table; deduced places for Cloverdon station—table; mean error; other determinations.

LONGITUDE AND TIME.

1853	*88-*89	CAMBRIDGE AND LIVERPOOL CHRONOMETER-EXPEDITIONS IN 1849, 1850, AND 1851.—G. P. Bond.—Computations of results for determining difference of longitude.
1854	*138-*142	CHRONOMETRIC LONGITUDE-EXPEDITIONS, (CAMBRIDGE-LIVERPOOL.)—G. P. Bond.—Results of the expeditions of 1849, 1850, and 1851, and on the method of computation.—[Errata, 140: 1855, p. XIX.]
1855	275-276	CHRONOMETRIC LONGITUDES.—W. C. Bond.—On moon-culminations observed by him, and the chronometric expedition for determining the longitude-difference between Cambridge, Mass., and Liverpool, England.—[Errata, 275: 1855, p. XVIII.)
1856	182-191	CHRONOMETRIC RESULTS.—G. P. Bond.—Results of the chronometric expeditions of 1849, 1850, 1851, and 1855 for difference of longitude between Cambridge, Mass., and Liverpool, England—table of longitudes by voyages of 1855.
1857	314-324	CHRONOMETRIC DETERMINATION OF THE DIFFERENCE OF LONGITUDE BETWEEN SAVANNAH, GA., AND FERNANDINA, FLA., AND DISCUSSION OF THE METHOD.—A. D. Bache and C. A. Schott.—Chronometers used; personal equation; temperature-compensation; chronometer-comparisons—table; stationary and traveling rates—tables of comparison, and discussion.

GEODESY—LONGITUDE AND TIME—Continued.

Year.	Pages.	Title of papers.
1851	480–481	LONGITUDE OF HARVARD OBSERVATORY.—S. C. Walker.—By moon-culminations, eclipses, transits, occultations, and telegraph.
1866	99–100	LONGITUDE.—[From Report for 1846.]—S. C. Walker.—Difference of longitude between Philadelphia and Greenwich by reduction of Cambridge (Mass.) observations.
1866	102–105	LONGITUDE.—[From Report for 1848.]—S. C. Walker.—Difference of longitude between New York, Cambridge, and Greenwich.
1866	111–112	LONGITUDES.—[From Report for 1851.]—C. L. Walker.—Harvard observatory, west of Greenwich; by moon, eclipses, transits, and occultations; result.
1867	57–133	LONGITUDE, TRANSATLANTIC.—B. A. Gould.—1, Origin of the Coast Survey expedition in 1866; 2, previous determinations of transatlantic longitudes from eclipses and occultations, from moon-culminations; from chronometers transported from Boston to Liverpool; 3, history of the expedition; programme of transatlantic-longitude campaign; 4, observations at Valencia; table of equatorial intervals; table of observations, October 25 to November 16, 1866; 5, observations at Newfoundland, October 25 to December 16, 1866; 6, observations at Calais, December 11 to 18, 1866; 7, longitude-signals between Foilhommerum and Heart's Content; clock-corrections; transatlantic longitude and transmission-time, October 25 to November 9, 1866; 8, longitude-signals between Heart's Content and Calais; tables of Newfoundland and Calais signals; tables of longitude and times of transmission; 9, personal error in noting signals; 10, personal equation determining time; 11, final results for longitude; 12, velocity of transmission; cables of 1860 and 1865; tables of comparison.
1851	476–479	MEASURES OF WAVE-TIME, MADE FROM 1849 TO 1851.—S. C. Walker.—Specifications and tables of results.
1866	106–108	LONGITUDES.—[From Report for 1850.]—S. C. Walker.—1, experiments for galvanic-wave time between Washington, D. C., and Saint Louis, Mo.; 2, attempted experiments on wave-time through different conductors; 3, experiments with the chemical-telegraph line; 4, progress of the researches on the velocity of the galvanic current.
1866	109–111	GALVANIC-WAVE TIME.—[From Report for 1851.]—C. S. Walker.—On measurements from 1849 to 1851, with tables.
1863	205	INDUCTION-TIME IN RELAY- MAGNETS.—G. W. Dean.—Report on experiments made to determine their relative power.
1864	211–220	EDUCTION-TIME OF RELAY-MAGNETS, DEDUCED FROM EXPERIMENTS.—G. W. Dean.
1851	462–463	TELEGRAPHIC ARRANGEMENT TO DETERMINE THE DIFFERENCE OF LONGITUDE BETWEEN CAMBRIDGE AND HALIFAX.—S. C. Walker.
1853	*86–*88	TELEGRAPHIC LONGITUDE OF CHARLESTON, S. C.—B. A. Gould.—Results of observations for the determination of difference of longitude by telegraph between Seaton station (Washington, D. C.) and Charleston, S. C.
1854	*128–*131	TELEGRAPHIC LONGITUDE.—B. A. Gould.—On telegraphic observations for the difference of longitude between Raleigh, N. C., and Columbia, S. C.
1855	286–295	TELEGRAPHIC LONGITUDES.—B. A. Gould.—Report on telegraphic operations for difference of longitude between Columbia, S. C., and Macon, Ga.; programme of telegraphic campaign; for instrumental corrections and longitude-reductions; battery-memoranda; to put up Kessel's clock.—[Errata, 288: 1855, p. XVIII.]
1856	167–181	TELEGRAPHIC METHOD.—G. W. Dean.—Details of the method used in the Coast Survey for telegraphic-determinations of difference of longitude; transit-instrument; astronomical clock; chronographic register; batteries; list of stars arranged from the British Association Catalogue for determining the difference of longitude between Macon, Ga., and Montgomery, Ala., March, 1856; exchange of star-signals; reading off the chronographic sheets; example of reduction; observations for determining the inequality of the pivots of Coast Survey transit No. 8; personal equations.—[Sketch 66.]—[Errata, 169–170: 1856, p. XX.]
1856	163–166	TELEGRAPHIC.—B. A. Gould.—Operations for difference of longitude between Wilmington, N. C., and Montgomery, Ala., with list of stars for observation.
1857	305–310	TELEGRAPHIC LONGITUDES.—On the progress made in the different campaigns.—B. A. Gould.—List of time-stars adopted; difficulties and discrepancies of transmission for signals between Wilmington, N. C., and Columbia, S. C.
1861	221–232	LONGITUDE OF ALBANY, N. Y.—B. A. Gould.—Abstract of a report on the determination by telegraph of the difference of longitude between New York City and Albany; table of instrumental corrections; collimation and azimuth-correction, and hourly clock-rate; personal equations; comparative table of clock-values gained at opposite stations.
1862	158–160	LONGITUDES IN MAINE, ALABAMA, AND FLORIDA.—B. A. Gould.—On progress in computing results from telegraphic observations.
1863	154–156	LONGITUDE.—B. A. Gould.—On computations connected with the telegraphic method.
1864	115–116	ON RESULTS BY TELEGRAPHIC METHOD.—B. A. Gould.
1865	150–151	REPORT ON THE RESULTS OF DETERMINING LONGITUDE BY TELEGRAPHIC METHOD.—B. A. Gould.
1866	100–102	LONGITUDE.—[Report for 1846.]—S. C. Walker.
1870	100	Results of the telegraphic determination of the longitude of San Francisco, Cal.
1870	101–106	Abstracts of results for difference of longitude between Harvard observatory, Massachusetts, the Coast Survey station Seaton, and the Naval Observatory, Washington, D. C., by Prof. Joseph Winlock, of Harvard observatory, and Commodore B. F. Sands, U. S. N.
1856	203–208	OCCULTATIONS ON THE WESTERN COAST.—G. Davidson.—Observations made at Port Townshend, Washington Territory, April and May, 1856; tables and remarks.
1855	267–274	LONGITUDES.—Report on the method of determining longitudes by occultations of the Pleiades.—Benjamin Peirce.—[Errata, 268, 269, 270, 272, 273: 1855, p. XVIII.]
1856	191–197	PLEIADES.—Benjamin Peirce.—On the determination of longitude by occultations; formulas for the correction of the co-ordinates of the stars; table for 1840; table of logarithms for h and k for the principal observatories.
1857	311–314	LONGITUDE-METHODS.—Benjamin Peirce.—On the relative precision of determinations by occultations and solar eclipses; upon the use of the solar eclipses; upon the occultations of the Pleiades.
1861	196–221	LONGITUDE.—Benjamin Peirce.—Report on the determination of longitude by occultations of the Pleiades, with an example showing the mode of computation; Greenwich, Cambridge, (England,) Ashurst, Washington City, Philadelphia, and Boston observatories computed; solution of the equations for the correlation of the moon's place and of the longitude.

GEODESY—LONGITUDE AND TIME—Continued.

Year.	Pages.	Title of papers.
1862..	155-156	LONGITUDE OF AMERICA FROM EUROPE.—Benjamin Peirce.—On the result from occultation of the Pleiades.
1862..	157-158	LUNAR TABLES USED IN REDUCING OBSERVATIONS OF THE PLEIADES FOR LONGITUDE.—Benjamin Peirce.—On their progressive improvements.
1863..	146-154	OCCULTATIONS OF THE PLEIADES IN 1841-'42.—Benjamin Peirce.—On computations for longitude, Nos. I, II, and V; records of Edinburgh, Washington, and Cambridge observations; ephemeris; stereographic co-ordinates of the moon referred to Alcyone; equations for the correction of the moon's place and of the longitude; solutions.
1864..	114	LONGITUDE.—On the method of determining by occultations of the Pleiades.—Benjamin Peirce.
1865..	138-146	REPORT ON THE PROGRESS OF DETERMINING LONGITUDE FROM OCCULTATIONS OF THE PLEIADES, CONTINUED FROM PREVIOUS REPORTS.—Benjamin Peirce.—Values of Σ_2-p for 1838-'42 and 1857-'61.
1865..	146-149	METHOD OF DETERMINING LONGITUDE FROM THE OCCULTATIONS OF THE PLEIADES, CONTINUED FROM PREVIOUS REPORTS.—Benjamin Peirce.—Corrections of lunar semi-diameter, mean place, ellipticity of orbit, longitude of perihelion, co-efficient of annual parallax, and longitude of Europe and America; example.
1853..	*84	ON LONGITUDE FROM MOON-CULMINATIONS.—Benjamin Peirce.—On the determination of longitude from observations of moon-culminations; standard probable error of observation of interpolated lunar transits; constant errors of epoch and periodical one of half-lunations.
1853..	*84-*86	ON MOON-CULMINATION OBSERVED BY THE "AMERICAN METHOD," WITH REMARKS ON THE PERFORMANCE OF BOND'S "SPRING-GOVERNOR."—W. C. Bond.—Comparison of records made by two spring-governors differing one-tenth of a second in time of pendular vibration; table of star-transits; amount of probable errors.
1854	108-120	LONGITUDE BY MOON CULMINATIONS.—Benjamin Peirce.—General considerations; constant errors and personal equations; correction of the lunar ephemeris; standard probable error of observation of a lunar transit; limit of accuracy attainable; longitude of the National Observatory, Washington, D. C.; three forms of correcting lunar ephemeris and the modes of computation.—[Errata, 112, 113, 114, 115, 117: 1855, p. XIX.]
1854	*120	MOON-CULMINATIONS.—W. C. Bond.—Observed by the American method; chronometric longitude of Cambridge and probable error.
1854	*120	MOON-CULMINATIONS.—E. O. Kendall.—Observed at High School observatory, Philadelphia.
1856	181	CHRONOMETRIC AND ASTRONOMICAL.—W. C. Bond.—On longitude-computations and occultations observed; lunar-spot transits.
1856	198-203	LUNAR-SPOT TRANSITS.—C. H. F. Peters.—On the substitution of lunar spots for the moon's limb in observing culminations.
1858	186-189	LONGITUDES.—Method of computing from moon-culminations; notes on observations of moon-culminations; forms and example.
1858	190	MOON-CULMINATIONS, ETC.—O. M. Mitchel.—Number of observations made by him for the Coast Survey.
1857	310 311	MOON-CULMINATIONS.—W. C. Bond.—On the number observed during the year at Cambridge, co-operative with those on the Pacific side; star-occultation photographs; connection with Quebec.
1859	278	MOON-CULMINATIONS.—O. M. Mitchel.—Observations made for the Coast Survey at the Cincinnati observatory for longitude-purposes.
1861	182-195	LONGITUDE.—Benjamin Peirce.—Discussion of observations of the solar eclipse of July, 1851; observations of the total phase; European observations, of which the beginning and the end, both observed at the same place, have been admitted into the computation; American observations; method of computation.
1854	121	Discussion of probable error of observation at Würdemann's (26-inch) portable transit; from observations by G. Davidson in 1853. [Report of 1866, Sketch 29.]—By J. E. Hilgard.
1855	276-278	Description of Würdemann's zenith-telescope of 1855, used at Dixmont, Me.—By G. W. Dean.
1866	55-71	The transit-instrument, description, use, adjustment, and method of observation.—By C. A. Schott.
1867	138 139	Meridian and equal-altitude instruments.—By George Davidson.—[Sketch 28.]
1868	154-157	Addenda to Appendix No. 9, Coast Survey Report for 1866, on the determination of time by means of the transit instrument.—By C. A. Schott.
1869	226-232	On the use of the zenith-telescope for observations of time, with an example of observation.—By J. E. Hilgard.

AZIMUTH.

1856	208-209	AZIMUTH.—J. E. Hilgard.—Method of using the transit-instrument for azimuth-observations; residual errors of graduation and readings.
1866	86-99	ASTRONOMICAL AZIMUTH.—C. A. Schott.—1, principal methods; 2, astronomical azimuth; 3, geodetic azimuth; 4, primary and secondary azimuths; 5, time; 6, instruments used; 7, azimuth-marks; 8, errors eliminated; 9, circumpolar stars used.
1868	157-165	[SUPPLEMENT, 1868, p. 157.—Specimen-table of local times of elongations and culminations of four circumpolar stars for 1873, latitude 40°, longitude 6*h*. west of Greenwich; correction for altered dates and latitudes.]—10, high stars; 11, sets of observations; 12, method of recording and reducing; 13, observations of a close circumpolar star near its elongation.—[SUPPLEMENT, p. 158.—In vertical of star; example of record and reduction; micrometer-values; deduction of azimuth.]—14, at any hour-angle; 15, computation by fundamental trigonometrical formula; 16, by Napier's analogies; 17, by a development into a series; 18, at equal intervals before and after culmination.—[SUPPLEMENT, p. 160.—(*a*,) near culmination; example of record and computation; eye-piece micrometer, values determined and applied to level-correction; (*b*,) pivot-micrometer, ditto, with example and record of reduction; single micrometer-turn, ditto; discussion of set of four stars; centering of instrument for connection with triangulations.]—19, observation of sun for azimuth; 20, examples of records and reductions to articles 11, 13, 14, 15, 17, 18, and 19.—[Sketches 26 and 27.]
1870	178-179	CHANGES OF ELEVATION AND AZIMUTH caused by the action of the sun at station Dominguez, Cal.—By George Davidson.
1870	226-227	AZIMUTH AND APPARENT ALTITUDE OF POLARIS.—By George Davidson.

GEODESY—BASE-LINES

Year.	Pages.	Title of papers.
1865	187–203	RESULTS OF THE PRIMARY TRIANGULATION OF THE COAST OF NEW ENGLAND, from the northeastern boundary to the vicinity of New York; length and accuracy of the Fire Island base-line; length and accuracy of the Massachusetts base-line; length and accuracy of Epping base-line; geodetic connection of the three primary base-lines in Maine, Massachusetts, and New York, their degree of accordance and resulting accuracy of the primary triangulation intervening; resulting angles and distances of the primary triangulation between the Epping (Mass.) and Fire Island base-lines.—[Errata, 198: 1866, p. 141.]
1866	49–54	PRIMARY TRIANGULATION OF THE ATLANTIC COAST.—C. A. Schott.—Geodetic connection of the two primary base-lines in New York and Maryland, their degree of accordance and accuracy of the primary triangulation invervening, with the resulting angles and distances as finally adjusted.
1869	105–112	CONNECTION OF THE PRIMARY BASE-LINES of Kent Island, Md., and on Craney Island, Va., and on the degree of accuracy of the intervening primary and subprimary triangulations.—C. A. Schott.—Statistics of conditions; linear discrepancies in the base-lines; degree of accuracy; final correction of directions; adjustment of the subprimary stations; Cape Charles height and north end of measurement; adjustment of the secondary station, Hampton Seminary; table of Atlantic series of primary triangles continued.
1867	134–137	COMPARISON OF METERS.—F. A. P. Barnard and M. Tresch.—Comparison of an iron meter forwarded to France by the Government of the United States of America; Table I, the United States meter upon the comparator; II, the Conservatoire standard upon the comparator; III, the United States meter upon the comparator; IV, results.
1868	147–153	RESULTS OF THE MEASUREMENT OF AN ARC OF THE MERIDIAN.—C. A. Schott.—Length of the arc by four methods; accuracy of the preceding results; table and diagram; determination of the astronomical latitudes; recapitulation of results.
1854	*103–*108	BASE-MEASURING APPARATUS, description of, as used in the Coast Survey.—Lieut. E. B. Hunt, U. S. Eng'rs.—[Sketch 54.]
1855	264–267	PRELIMINARY BASE-APPARATUS.—C. O. Boutelle.—[Sketch 53.]
1856	308–310	SUBSIDIARY BASE-APPARATUS.—Description of a modification devised for ascertaining the temperature of rods in use.—[Sketch 64.]
1857	395–398	BASE-APPARATUS for measuring subsidiary lines; description.—J. E. Hilgard.—[Sketch 69.]
1862	248–255	BASE-MEASURING APPARATUS.—J. E. Hilgard.—Abstract of experiments for determining the length and expansion by heat of the standard bar, with table of comparisons of standard bar with 6 meters.—[Sketch 49.]
1857	302–305	EPPING BASE, MAINE.—A. D. Bache.—Notes on the preparation of site, measurement of line, and progress, as compared with other measurements of the Coast Survey.—[Sketch 3.]
1864	120–144	EPPING BASE-LINE.—C. A. Schott.—Report on the method of computation and resulting connection with the primary triangulation.—1, general remarks on the method of reduction; 2, instruments and methods of horizontal measures employed in the triangulation near the Epping base; 3, determination of probable error and weight to each direction observed with the 30-inch theodolite; station Howard; abstract of remaining differences; abstract of remaining errors—table; 4, determination of probable error and weight to each angle and direction from observations with a repeating-circle; 5, resulting horizontal angles from the observations at each station, with their probable error; 6, effects upon the horizontal angles of a difference of level between the stations occupied and observed upon; 7, spherical excess of triangles; 8, residuals in the sum of angles of each triangle, and their discussion; 9, final determination of probable errors (and weights) to each direction; 10, relative value of results from the 30-inch and the 10-inch repeating-theodolites; 11, formation of the conditional equation of the nonagon around the Epping base; 12, equation of correlatives and normal equations; 13, resulting correction to the observed directions; 14, complete adjustment of the nonagon and final directions; 15, triangle side-computations; 16, resulting distances from Mount Desert to Humpback; 17, connection of the azimuth-mark with the adjusted directions.—[Errata, 143: 1866, p. 141.]
1868	133–139	Full explanation of the different successive operations connected with the measurement of a subsidiary base-line.
1866	140	Length of the Kent Island base-line.—[Supplement to C. A. Schott's report on primary triangulation of the same year.]

GEOGRAPHICAL POSITIONS.

1851	102–442	LIST OF GEOGRAPHICAL POSITIONS determined by the Coast Survey; sections; method of triangulation and verification; average error; assumed size and form of the globe; station-errors; checking of geodetic longitudes by telegraph; longitude of Cambridge from Greenwich; explanation of tables; list.—[Errata, 168, 169, 218, 304, 324, 372, 374, 375, 378: 1851, p. VIII; Errata, 163, 169, 189, 190, 191, 194, 217, 218, 220, 258, 271, 276, 286, 324, 360, 372, 374, 375, 378, 400, 402, 404, 409, 416, 425, 480: 1853, p. *181; Errata, 185, 252: 1854, p. XII; Errata, 192, 225, 340, 341, 342, 344, 346, 411: 1855, p. XVIII.]
1853	*14–*42	List of geographical positions.—[Errata, *15, *16, *et seq.*, *17, *20, *28, *29, *31, *32, *33, *34, *36, *42: 1854, p. XII; Errata, *19, *20: 1855, p. XVIII.]
1855	119–148	List of geographical positions.—[Errata, 138–140: 1856, p. XX.]
1857	264–301	List of geographical positions.
1859	216–277	List of geographical positions.
1864	144–182	List of geographical positions.
1865	99–136	List of geographical positions in Sections V, VI, VII, and IX.
1865	137	List of geographical positions determined approximately in West Virginia, Kentucky, Tennessee, Alabama, Mississippi, and Missouri.
1868	171–242	List of geographical positions determined by the Coast Survey.

GEODESY—GEOGRAPHICAL POSITIONS—TOPOGRAPHICAL AND HYDROGRAPHIC SHEETS.

Year.	Pages.	Title of papers.
1857	223-264	LIST OF TOPOGRAPHICAL AND HYDROGRAPHIC SHEETS, showing their titles, dates, scale, and register-number, as filed in the office.
1859	212-216	List of topographical and hydrographic sheets continued.
1861	176-180	List of topographical and hydrographic sheets continued.
1863	143-146	List of topographical and hydrographic sheets continued.
1865	50-99	List of topographical and hydrographic sheets continued.
1867	265-274	List of topographical and hydrographic sheets of Alaska, by Russian authority.
1860	361-391	Formulas for computing latitudes, longitudes, and azimuths, with an example as used in the Coast Survey Office, and tables for each minute of latitude from 23° to 50°.

ASTRONOMY.

Year.	Pages.	Title of papers.
1854	*122-*127	SOLAR ECLIPSE, MAY 26, 1854.—Observations made at Brooklyn, Long Island, reported by E. Blunt; at Seaton station, Washington, D. C., by C. O. Boutelle; at Roslyn station, near Petersburgh, Va, by L. F. Pourtales; Black Mountain station, Cal., by R. D. Cutts; Benicia, Cal., by R. D. Cutts; Humboldt Bay, Cal., by G. Davidson.
1855	278-286	STAR-CATALOGUES.—C. A. Schott.—Comparison of star-places given in Rümker's and the Twelve Year Catalogues.—Table I, comparison of right ascensions; II, of north polar distances.
1860	229-275	SOLAR ECLIPSE, JULY 18, 1860.—Prof. Steph. Alexander.—Results of the expedition to Aulezavik Island, Labrador, to observe the eclipse of the 18th of July, 1860; tabular comparison of chronometers; arrangement and programme; description of the telescope employed; synopsis of the observations; times of contacts; same in local mean time, (civil reckoning;) other observations; reports from special parties; earth-temperature, (Aulezavik;) atmospherical electricity; icebergs; mirage, &c.; triple rainbow; auroras; table of meteorological observations made during the hours corresponding to the eclipse, at Aulezavik, from July 14 to July 23; during the continuance of auroras *passim*; observations with Arago's polariscope; report of photographers; changes of illumination; seamen's observations; winds; magnetic elements; longitude by chronometer.—[Sketch 39.]—[Errata 239, 275: 1860, p. xx.]
1860	275-292	SOLAR ECLIPSE.—J. M. Gillis.—On the results of observations made near Fort Steilacoom, Washington Territory, on the solar eclipse of July 18, 1860; preliminary; table of meteorological observations on Muck Prairie; latitude-observations; time-observations; chronometer errors and rates; longitude; the eclipse; reports from special parties.
1861	232-239	SOLAR ECLIPSE OF JULY, 1860.—A. D. Bache.—Abstract of observations made at Gunstock Mountain, N. H.; 1, dispositions; 2, first contact; 3, positions of spots; I, table of observations, July 17; II, July 18, before; III, during; IV, after the eclipse; 4, occultation of spots; 5, last contact; 6, phenomena.—[Sketch 29.]—[Errata, 232: 1862, front leaf.]
1861	239-241	SOLAR ECLIPSE OF JULY, 1860.—C. A. Schott.—Abstract of observations made at the Coast Survey Office, Washington, D. C.; first contact; last contact; after the eclipse; heliographic position of the spots.
1861	241-242	SOLAR ECLIPSE OF JULY, 1860.—B. A. Gould.—Abstract of observations made at Cambridge, Mass.
1870	115-177	Reports of observations upon the solar eclipse of December 22, 1870; extent of the corona as indicated by the spectroscope, p. 150; nature of the coronal envelope and its relation to the sun, p. 152; constitution of the solar atmosphere, p. 153; suggestions with reference to the observation of future eclipses, pp. 154-158.
1870	229	Report on the solar eclipse of December 22, 1870.—By Prof. Benjamin Peirce, LL. D.—[From report for 1871.]
1869	116-198	SOLAR ECLIPSE, AUGUST 7, 1869.—Reports of observations of the eclipse of the sun on August 7, 1869, made by parties of the Coast Survey at the following stations: Bristol, Tenn., in charge of R. D. Cutts; Shelbyville, Ky., J. Winlock and G. W. Dean; Springfield, Ill., C. A. Schott; Des Moines, Iowa, J. E. Hilgard; and Kohklux, Chilkaht River, Alaska, G. Davidson — General path of the eclipse; contacts; obscuration of solar spots; breaking of sun's limb by lunar asperities; effects of optical inaccuracies; totality; protuberances; corona; emergence; northern and southern limits of totality ascertained; spectroscopic observations; photographic records; reduction of micrometric photograph-measures; deviation of photographed sun's outline from a circle, after corrections; computations of results.—[Sketches 24, 25, and 26.]—[Errata 165.]
1869	113-115	LOCAL DEFLECTIONS of the zenith in the vicinity of Washington City.—Report by Charles A. Schott.
1851	137-145	PROF. O. M. MITCHEL.—Report on a new method of recording differences of north polar distances, or declination, by electro-magnetism.
1861	259-261	SOLAR SPOTS.—C. A. Schott.—Abstract of observations made at the Coast Survey Office, Washington, D. C.; table from August, 1860, to December, 1861, and monthly relative numbers, compared with Wolf's revised numbers; spotless days.—[Sketch 29.]
1862	231-232	SOLAR SPOTS.—Continuation of preceding paper.
1865	152-154	REPORT AND TABLES on the declinations of standard time-stars.—B. A. Gould.
1865	155-159	REPORT AND TABLES on the positions and proper motions of the four polar stars.—B. A. Gould.

MATHEMATICS.

Year.	Pages.	Title of papers.
1854	63-70	COMPUTATION OF TRIANGULATION.—Comparison of the reduction of horizontal angles by the methods of "dependent directions" and of "dependent angular quantities" by the method of least squares.—Prof. A. D. Bache.—[Sketch 58.]—[Errata, 65, 70, 72, 75, 78, 79, 91, 94: 1855, p. XIX.]
1854	70-86	ADJUSTMENT OF HORIZONTAL ANGLES.—Charles A. Schott.
1854	86-95	PROBABLE ERROR OF OBSERVATION, derived from observations of horizontal angles at any single station and depending on directions.—Charles A. Schott.
1854	131-138	BENJAMIN PEIRCE'S CRITERION for the rejection of doubtful observations.—B. A. Gould.—[Errata, p. *138.]
1856	307-308	PROBABLE ERROR.—Article from "Astronomische Nachrichten, No. 1034," translated by Charles A. Schott.—Determination of the probable error of an observation by the differences of their observations from their arithmetical mean.
1870	200-224	ON THE THEORY OF ERRORS of observations.—C. S. Peirce.
1855	255-264	NORMAL EQUATIONS.—Charles A. Schott.—Solution of normal equations by indirect elimination.
1860	392-396	CAUCHY'S INTERPOLATION-FORMULAS; with remarks by Charles A. Schott.
1864	116-119	PROBLEM IN GEODESY.—Determining a position by angles observed from it on any number of stations.
1869	235	SOLUTION OF THE THREE-POINT PROBLEM, by determining the point of intersection of a side of the given triangle with a line from the opposite point to the unknown point.—A. Lindenkohl.

SURVEYING.

TRIANGULATION.

Year.	Pages.	Title of papers.
1855	363-364	FARLEY'S SIGNAL.—J. Farley.—Description and drawing of a convenient signal for observing on secondary stations.—[Sketch 52.]
1855	364	SANDS'S HELIOTROPE.—B. F. Sands.—Description and drawing of a convenient signal for observing on secondary stations.—[Sketch 55.]
1855	361-363	BOUTELLE'S TRIPOD AND SCAFFOLD.—C. O. Boutelle.—Description of, as constructed and used by him at the stations of the primary triangulation in Section V.—[Sketch 52.]
1856	291-292	MISSISSIPPI SOUND.—J. E. Hilgard.—Details of the work of triangulation; signals and station-marks.
1856	310-316	THEODOLITE-TEST.—J. E. Hilgard.—Examination and trials made of a ten-inch theodolite, applicable to the testing of instruments of like construction.—Table I, readings of every 10 degrees on the circle, and determination of angular distance of verniers; II, determination of eccentricity; III, residual errors of graduation and readings; figure of pivots.
1860	357-361	REPEATING-THEODOLITE.—Supplement to the method of testing (described in the preceding paper.)—Table I, readings of every 10 degrees on the circle, and determination of angular distance of verniers; II, determination of eccentricity; III, residual errors of graduation and readings.
1867	140-144	RAILWAYS, on the use of, for geodetic surveys.—J. E. Hilgard.—Wheel-records; linear measurement; rectification of curves; reduction of the measured lines and angles to a simpler system.—[Sketch 26.]
1867	145	REFLECTOR.—J. E. Hilgard.—Description of a new form of geodetic signals.—[Sketch 26.]
1868	109-139	MEMORANDA RELATING TO THE FIELD-WORK OF A SECONDARY TRIANGULATION.—R. D. Cutts.—Selection of stations; names of stations; signals; tripods and scaffolds; underground station-marks; surface station-marks; observations and records; number of observations; limit of error; probable error; reduction to center; correction for phase; correction for eccentricity; spherical excess; distribution of error; trigonometrical leveling; co-efficient of refraction; three-point problem; rectangular co-ordinates; measurements of subsidiary base-lines; records, duplicates, and computations.
1868	140-146	METHOD OF ADJUSTMENT OF THE SECONDARY TRIANGULATION OF LONG ISLAND SOUND.—C. A. Schott.—Example of reduction of angular measure of Shelter Island; final computation and proof of correctness.

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1854	*95-*103	MEASUREMENT OF HEIGHTS.—T. J. Cram.—Experimental comparison of the methods of measuring heights by leveling, by vertical angles, by the barometer, and by the boiling-point apparatus.—[Errata, 102: 1855, p. XIX.]
1860	397	TABLE OF HEIGHTS FOR THE USE OF TOPOGRAPHERS.—C. A. Schott.—Height in feet corresponding to a given angle of elevation and a given distance in meters, for use in the construction of contour-lines by plane-tables.
1870	75-76	REPORT ON THE LEVELING-OPERATIONS between Keyport, on Raritan Bay, and Gloucester, on the Delaware River, to determine the heights above mean tide of the primary stations Beacon Hill, Disborough, Stony Hill, Mount Holly, and Pine Hill.—By Assistant Richard D. Cutts.—Heights above mean-tide, determined by the spirit-level, p. 75; tidal stations, p. 75; instruments, p. 75; tidal observations and records, p. 76.
1870	77-89	REPORT ON THE RESULTS OF BAROMETRICAL OBSERVATIONS made in connection with the line of spirit-leveling from Raritan Bay to the Delaware River to determine the heights, &c.—By Assistant Richard D. Cutts.—Comparison of instruments, and the determination of personal errors, pp. 77-81; the computations, pp. 81-89.
1870	90-91	List of heights, above the half-tide level of the ocean, of trigonometrical stations determined by the United States Coast Survey.

SURVEYING—TOPOGRAPHY—Continued.

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1865	203-231	TREATISE ON THE PLANE-TABLE AND ITS USE, with diagrams.—A. M. Harrison.—Description; adjustments; paper; scales; projections for field-work; three-point problem; practicable modes of determining the position of a fourth point by resection upon three fixed points; Lehmann's method; Netto's method; Bessel's methods; two-point problem; field-work; contours; example; table of heights; chain; telemeter; table for reduction of hypothenuse to base; reconnaissance; office-work.—[Sketches 30, 31, 32.]
1855	162-163	NEW YORK CITY.—Report of F. H. Gerdes on his topographical survey of Manhattan Island.
1855	164-165	REPORT ON TOPOGRAPHY executed by the party of Assistant A. M. Harrison on the coast of New Jersey.
1855	164	REPORT ON TOPOGRAPHY executed by the party of Assistant S. A. Gilbert on the western and southern sides of Long Island.
1856	281-282	COMPARATIVE MAPS, NEW YORK HARBOR.—A. Boschke.—Method of survey.

HYDROGRAPHY.

1859	311-317	PILE FOR SECURING TIDE-GAUGES, Mitchell's.—[Sketch 40.]—(*See* 311-317, New York Harbor.)
1853	*94-*96	SELF-REGISTERING TIDE-GAUGE, Saxton's.—E. B. Hunt.—[Sketch 54.]
1854	*190*-191	SEA-COAST TIDE-GAUGE.—H. Mitchell.—Description of his tide-gauge used at stations on the open sea-coast and in situations exposed to stormy currents.—[Sketch 57.]—(*See, also,* *35-*37.)—[Errata, for Sketch K read Sketch 57.]
1857	402-403	TIDE-GAUGE, Trenchard's.—[Sketch 72.]
1857	403-404	TIDE-GAGUE FOR DEEP WATER, Mitchell's.—[Sketch 72.]
1858	247-248	SOUNDING-APPARATUS AND TIDE-METER, proposed by E. B. Hunt.—Notes on its principles and application.—J. M. Batchelder.
1857	398-401	SOUNDING-APPARATUS.—New method proposed by E. B. Hunt for sounding in moderate depths.
1859	365-366	TIDE-METER.—Results of experiments made with the apparatus devised by E. B. Hunt.—J. M. Batchelder.
1857	398	DEEP-SEA-SOUNDING APPARATUS.—Description of a form proposed and used by B. F. Sands.—[Sketch 70.]
1857	401-402	EXPERIMENTAL SOUNDINGS made with Hunt's sounding-apparatus.—W. G. Temple.
1857	....	BERRYMAN-BROOKS'S DEEP-SEA SOUNDING-APPARATUS.—[Sketch 71.]
1859	359-364	DEEP-SEA-SOUNDING APPARATUS.—Description of a form devised by W. P. Trowbridge, and explanation of its method and use.—[Sketch 39.]—[Errata, 359, 1860, p. XX.]
1861	135-139	SOUNDING-APPARATUS AND LOG.—W. P. Trowbridge.—Results obtained with an instrument devised by him.
1866	139	BERRYMAN APPARATUS; rates of outrun of line.—(*See* 1857, Specimen sounding, Sketch 71.)
1854	*191-*192	CRAVEN'S SPECIMEN-BOX for deep-sea bottoms.—T. A. Craven.—[Sketch 56.]
1855	361	SPECIMEN-BOX.—B. F. Sands.—Instrument for procuring specimens of bottoms in sounding.—[Sketch 55.]
1860	398	(Specimen) SOUNDING-APPARATUS, Mitchell's, for shallow water.—[Sketch 40.]
1854	....	CRAVEN'S CURRENT-INDICATOR.—[Sketch 55.]
1855	365-366	SANDS'S HYDROGRAPHIC SIGNAL.—B. F. Sands.—Description and drawing of his gas-pipe signal used in the breakers on Dog Island Bar.—[Sketch 54.]
1852	97-98	SCREW-PILE SIGNALS along Florida Reef.—James Totten.
1855	157-160	FLORIDA REEF SCREW-PILE BEACONS.—Description of signals.—James Totten.
1853	*93-*94	ALIGNING REFLECTOR or interranger, Hunt's.—E. B. Hunt.
1857	150-151	METHOD OF SWEEPING.—(*See* Depths at Hell-Gate, &c.)
1860	165-176	HYDROGRAPHICAL EXPLORATION.—*See* Gulf Stream; general account of the methods used in developing its hydrography, &c.—[Sketches 19-22.]
1856	133-137	Depths in channel-entrances of harbors, rivers, ports, and anchorages on the coasts of the United States.
1857	178-184	The same.—[Errata, 182, 183: 1857, p. XVIII.]
1859	168-171	The same.
1862	86-92	The same.

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1855	171-176	FLORIDA KEYS.—Survey for the General Land-Office, including reports on the general topography and triangulation, on the determination of the shore-line, and reconnaissance of Barnes's Sound, Florida.
1856	286-289	FLORIDA KEYS.—Report of the Superintendent to the Commissioner of the General Land-Office on progress made in the survey and marking in quarter-sections.
1857	379-382	FLORIDA PENINSULA AIR-LINE.—Report of a reconnaissance made between Fernandina and Cedar Keys.—By Capt. J. H. Simpson, United States Topographical Engineers.
1857	382-390	FLORIDA KEYS.—Superintendent's report to Commissioner of General Land-Office on progress made in survey and marking of the Keys.
1858	225-227	FLORIDA KEYS.—Superintendent's report to Commissioner of General Land-Office on progress made in survey and marking of the Keys—Continued.
1858	224	EASTERN COAST OF FLORIDA, south of Saint John's River.—Report of Sub-assistant J. Mechan on local characteristics.
1854	*28-*30	Extracts from the report of F. H. Gerdes on the reconnaissance of the coast of Louisiana in 1854, (Mississippi Delta.)
1852	87-94	Extracts from the report of Assistant F. H. Gerdes on a reconnaissance from Suwannee River, Florida, to Delta of Mississippi.
1852	104-107	Report of Lieut. Commander James Alden, U. S. N., on the reconnaissance from San Francisco to San Diego, including Santa Barbara Islands.
1857	390-391	COAST OF SANTA BARBARA CHANNEL.—Report of Sub-assistant W. M. Johnson on its topographical characteristics.
1857	391-395	SANTA BARBARA ISLANDS AND MAIN.—Report on the character and progress of the work.—By Assistant W. E. Greenwell.

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1854	*30-*31	Extracts from a report of W. E. Greenwell on the general features and peculiarities of the coast of Lower Texas, with suggestions in regard to facilities for navigation, from the harbor of the Brazos de Santiago to the mouth of the Rio Grande.
1859	324-328	COAST OF TEXAS, embracing the shores of Espiritu Santo, San Antonio, and Aransas Bays.—Report on a reconnaissance.—By Assistant S. A. Gilbert.
1860	356-357	CORPUS CHRISTI BAY AND LAGUNA MADRE, TEXAS.—General description of characteristics.—By Assistant S. A. Gilbert.
1861	263-264	COAST OF TEXAS above Galveston Bay.—Extracts from a descriptive report.—By Capt. George Bell, U. S. A.
1867	149-157	PROVINCETOWN HARBOR, MASSACHUSETTS.—Special survey.—Report by Assistant H. L. Whiting.

PHYSICAL HYDROGRAPHY.

Year.	Pages.	Title of papers.
1856	249-251	PREDICTION TABLES.—Notes on the progress made in their preparation with reference to tides of Boston Harbor.—A. D. Bache.
1868	51-102	TIDAL EPHEMERIS; and COMPUTATIONS.—(*See* LOCAL TIDES.)
1868	103-108	MODE OF FORMING A BRIEF TIDE-TABLE FOR A CHART, with example.—R. S. Avery.—[Sketch 29.]
1870	66-69	Tabular statements of results of computed tide-tables for charts of the western coast of the United States.—By R. S. Avery.
1870	70-74	MODE OF FORMING BRIEF PREDICTION TIDE-TABLES.—By R. S. Avery.
1869	75-104	RECLAMATION OF TIDE-LANDS, AND ITS RELATION TO NAVIGATION.—H. Mitchell.—1, general discussion; scour of tidal and river currents; general rule of bar-scouring; parallel works; transverse works; physical history of salt-marshes; shingle-levees; other natural levees; Peirce's criterion; 2, field-work; Green Harbor River; North River; tabular sections of shingle-levees; sand beach; section of slueway formed by Minot's gale; general rise; local changes of heights of tide—tables; effect of a dam; general conclusions relative to the projects of reclamation; shore of Nahant; tabular sections; maps and diagrams, (in text.)
1858	213-216	DYNAMICS OF OCEAN-CURRENTS.—E. B. Hunt.
1858	210-213	CO-TIDAL LINES of an inclosed sea, as derived from the equilibrium-theory.—Benjamin Peirce.—1, general theory; 2, its modification by the incompleteness of the inclosure.
1854	*147-*152	CO-TIDAL LINES, Atlantic.—A. D. Bache.—Preliminary determinations of co-tidal lines on the Atlantic coast of the United States, from Coast Survey observations.—Table I, observations for co tidal hours; II, co-tidal hours of ports on the Atlantic coast; III, rate and trend of co-tidal lines.—[Sketch 26.]—[Errata, 151: 1855, p. XIX.]
1856	252-260	CO-TIDAL LINES, Gulf of Mexico.—A. D. Bache.—Discussion and preliminary determination.—Table I, diurnal wave; II, stations, &c.; III, diurnal intervals; IV, tide-elements of the stations; V, semi-diurnal tides; VI, comparison of establishments of diurnal and semi-diurnal tides in the Gulf of Mexico.—[Sketches 35 and 36.]
1862	126-128	CO-TIDAL LINES OF THE GULF OF MEXICO, deduced from recent observations.—A. D. Bache.—Tables of diurnal and semi-diurnal tides.—[Sketch 46.]
1855	338-342	PACIFIC CO-TIDAL LINES.—A. D. Bache.—Tidal observations.—Table I, tide-stations on the western coast of the United States; II, data for co-tidal lines of the Pacific coast of the United States; co-tidal hours; co-tidal groups; III, discussion of the middle group between Cape Mendocino and Point Conception.—Chart of co-tidal lines.—[Sketch 49.]
1857	342-347	ATLANTIC COAST TIDES.—Generalization of heights relative to the configuration of the coast.—A. D. Bache.—Table I (A), heights of tides on the Atlantic coast of the United States; II (B), on the coast of Cape Breton and New Brunswick.—[Sketch 65.]
1868	51-102	DISCUSSION OF THE TIDES IN BOSTON HARBOR.—W. Ferrel.—The observations and the locality; expression of the disturbing forces; tidal expressions; object and plan of discussion.—Tables I, II, III, and IV, of average normal values; V, the constant or mean tide; the semi-monthly inequality; VI, inequality depending upon the moon's mean anomaly; VII, inequality depending upon the moon's longitude; VII *bis*, inequality depending upon the sun's anomaly and longitude; VIII, inequality depending upon the moon's node; IX, inequalities depending upon η_8 and η_9; diurnal tide; recapitulation of results; comparisons with the equilibrium theory; determination of the general constants; comparisons with the dynamic theory; prediction formulas and Tables I-XI; computation of a tidal ephemeris; conclusion; example of the computation of a tidal ephemeris.
1855	346-347	GULF OF MEXICO TIDES.—A. D. Bache.—Observations and type-curves at the several stations, showing their decomposition into diurnal and semi-diurnal tides.
1856	260-261	TYPE-CURVES, Gulf of Mexico.—Descriptive references to Sketch No. 38, representing the decomposition of curves of observations.—[Sketch 38.]
1854	*152-*155	DIURNAL INEQUALITY, WESTERN-COAST TIDES.—A. D. Bache.—Comparison of the diurnal inequality of the tides at San Diego, San Francisco, and Astoria, with tables.—[Sketch 49.]—[Errata, 153: 1855, p. XIX.]
1865	138	EXPLANATION OF DIAGRAM OF TYPE-CURVES of the tides on the Pacific Coast.—[Sketch 26.]
1856	271-272	WINDS OF ALBEMARLE SOUND.—Discussion of their effect upon the tides.—L. F. Pourtales.—[Sketch 16.]
1856	276-278	WINDS AND TIDES IN CAT ISLAND HARBOR.—Results deduced from observations made by G. W. Dean.—[Sketch 39.]
1856	272-276	WINDS IN THE GULF OF MEXICO.—A. D. Bache.—Discussion relative to the disturbance caused in the intervals of successive tides at several stations on the Gulf coast; Table I, quantity and direction of wind at Key West, Fla., 1851-'52; II, at Fort Morgan, Ala., 1847-'49; III, at Galveston, Tex.
1857	354-358	WINDS OF THE WESTERN COAST.—Discussion by Prof. A. D. Bache.
1856	279-280	CARDS FROM CURRENT-BOTTLES.—Picked up on the shore of Loggerhead Key, Fla., and on the North Caicos, Bahamas.
1859	320-321	CURRENT-CARDS thrown from the surveying-steamer Corwin, and found on the eastern coast of Florida.

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1854	*189-*190	CURRENT-BOTTLES.—One from Mobile Bay to Mosquito Inlet; and one from Cape Florida to Jupiter Inlet.
1854	*35-*37	NANTUCKET AND VINEYARD SOUND TIDES.—H. Mitchell.—Method of securing Mitchell's tide-gauge; remarks on swells.—[Sketch 57.]
1855	222-223	NANTUCKET SOUND.—H. Mitchell.—Tidal observations; interference-phenomena.
1856	261-263	INTERFERENCE-TIDES.—H. Mitchell.—On observations made in Nantucket and Martha's Vineyard Sounds.
1866	44-46	HELL GATE (East River, N. Y.) TIDES.—H. Mitchell.—Preliminary report on the interference-tides of Hell Gate, with directions for reducing the sounding.—Table of relative elevations of tidal planes from his observations; tides and currents of Hell Gate, from observations of 1857.
1867	158-169	TIDES AND CURRENTS OF HELL GATE, N. Y.—H. Mitchell.—General scheme of tides and currents: 1, general scheme of tidal interference; observations and results; curves; 2, tides from stations selected as characteristic for New York Harbor and its approaches, 1857-'58, with diagram; 3, intervals and heights of tides from simultaneous observations, May and June, 1857, arranged according to hour of transit; curves of half-monthly inequalities; 4, restoration of level between gauges at Hell Gate Ferry and Pot Cove, 1857; diagram; 5, currents of New York Harbor; general scheme of currents, graphic.
1853	*71-*76	NOTES ON TIDES AT KEY WEST.—A. D. Bache.—Table I, half-monthly inequality of tides, one year's observations; II, diurnal inequality, with formula; decomposition of the curves of observation; semi-diurnal tides; III, first six months; IV, second six months; V, the whole year; diurnal tides; VI, effect of moon's declination; VII, moon's age; changes of mean level; VIII, height of high water referred to moon's age, first and second months; IX, monthly mean level.—[Sketches 27, (F, No. 4,) and 28, (F, No. 5.)]
1851	127-136	NOTES ON CAT ISLAND TIDES.—A. D. Bache.—Discussion; table of diurnal and semi-diurnal curves.—[Sketch 35, (H, Nos. 2-6.)]
1852	111-122	DISCUSSION OF CAT ISLAND TIDES.—A. D. Bache.—Table I, Sketch 1, diurnal and semi-diurnal curves deduced from observations, with curves of sines; (A,) diurnal wave; heights and times; II, Sketch 2, maximum ordinates of diurnal curve, &c.; III, Sketch 3, effect of sun's declination on height; IV, effect of moon's parallax; V and VI, co-efficients; VII, computed diurnal ordinates compared with observations; VIII, Sketch 8, residuals classed by moon's ages; IX, same, corrected by change of cosines; X, difference of diurnal maximum ordinates, from last and from first methods of groups—semi-diurnal effect; XI, correction to maximum diurnal ordinate for high-water ordinate; XII to XV, further residual corrections; comparison with hypothesis; (B,) semi-diurnal curve; XVI, half-monthly inequality in height; XVII, discrepancies between observations and formula.—[Sketch 25, (H, Nos. 5-9.)]—[Errata, p. 115, 119, 121: 1853, p. 182.]
1866	113-119	TIDAL OBSERVATIONS AT CAT ISLAND, GULF OF MEXICO; notes of a discussion, by A. D. Bache.—(Report for 1851.)—[Sketch 30.]
1853	*77-*81	NOTES ON TIDES AT RINCON POINT, CAL.—A. D. Bache.—[Tables I to IV.]—[Sketch 48, (J, No. 7.)]
1853	*81-*82	NOTES ON THE TIDES AT SAN FRANCISCO, CAL.—A. D. Bache.
1854	*37-*40	WESTERN COAST TIDAL AND MAGNETIC OBSERVATIONS.—W. P. Trowbridge.
1864	91-92	TIDES AT TAHITI, SOUTH PACIFC OCEAN.—Their general character.—J. Rodgers.—[Sketch 40.]
1860	399-*402	LABRADOR EXPEDITION.—A. Murray.—Report of a voyage of steamer Bibb, and remarks on the winds and tides.
1870	92-97	DESCRIPTION OF BEACH-MARKS at tidal-stations.
1870	190-199	ON THE MOON'S MASS, as deduced from a discussion of the tides of Boston Harbor.—By William Ferrel, esq.
1867	170-175	MERRIMACK RIVER, MASSACHUSETTS.—H. Mitchell.—Surveys respecting its navigation, with tables.—[Sketch 2.]
1851	555-558	HELL GATE CHANNEL.—W. A. Bartlett.—Examination of reefs and changes produced by blasting.—[Sketch 8, (B, No. 4.)]—[Errata, p. IX.]
1852	84	ON POT ROCK, HELL GATE.—W. A. Bartlett.
1857	150-151	DEPTHS AT HELL GATE ON THE SEVERAL ROCKS.—W. G. Temple.—Method of "sweeping."
1854	*166-*168	MUSKEGET CHANNEL AND MARTHA'S VINEYARD CURRENTS.—Discussed by C. A. Schott.—Table showing the currents and rate of current in Muskeget Channel and of the northeast coast of Martha's Vineyard; velocity of current; duration of ebb, flood, and slack water; current-establishments.—[Sketch 14, (A, No. 13;) also, 1855, Sketch 6.]—[Errata, p. 167, 168: 1855, p. XIX.]
1854	*161-*166	NANTUCKET SHOALS CURRENT.—C. A. Schott.—On the currents of Nantucket Shoals, from Coast Survey current observations.—Table I, mean direction; II, maximum velocity; III, groups of luni-current intervals.—[Sketch 13, (A, No. 12.)]—[Errata, p. 165, 166: 1855, p. XIX.]
1869	236-259	REPORTS CONCERNING MARTHA'S VINEYARD AND NANTUCKET.—H. L. Whiting and H. Mitchell.—(A,) Edgartown Harbor, changes; Vineyard Haven, its character as a port of refuge and its present condition; Table I, exposure of anchorages in Provincetown Harbor; II, in Vineyard Haven; III, in Great Wood's Hole; IV, in Tarpaulin Cove; V, in Edgartown Roadstead; VI, in Old Stage Harbor; VII, in New Bedford Harbor and Quick's Hole; VIII, in Plymouth Harbor; IX, in Boston Harbor and Nantasket Roads; X, in Boston Harbor and Hull Bay; XI, in Boston Harbor and President's Roads and George's Roads; XII, in Marblehead Harbor; XIII, at Salem Harbor; XIV, at Gloucester Harbor; XV, in Lower Bay, New York Harbor; XVI, in Upper Bay, New York Harbor; XVII, anchorage-room and average exposure in the respective harbors.—(B,) surveys of summer, 1871: 1, physical aspect and peculiarities; 2, Edgartown tides, difference of heights; 3, Nantucket tide-table; 4, elements of the field-work.
1854	*168-*170	TIDES, LONG ISLAND SOUND AND APPROACHES.—C. A. Schott.—Table I, range or mean rise and fall of tides, to April, 1853; II, corrected or mean establishments, to April, 1853; III, set and maximum rates of ebb and flood streams; IV, luni-current interval for beginning of outgoing streams; eastern part of the sound, 1846-'47; western part of New York Bay and Channel, 1844; New York Harbor, 1844-'45; Hell Gate, 1845; Hell Gate and Throg's Neck, 1846; V, mean duration of slack-waters and of respective ebb and flood streams, from the middle (time) of one slack-water period to that of the next; VI, irregularity of luni-current intervals of successive tides.—[Sketch 16, (B, No. 2.)]—[Errata, p. 172, 174: 1855, p. XIX.]
1857	350-354	TIDES AND CURRENTS in the Nantucket and Vineyard Sounds and in East River.—H. Mitchell.—Hell Gate and vicinity, tides and currents; Hudson River levelings; Nantucket and Martha's Vineyard Sounds, tides and currents.

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1851	136-137	GRAPHICAL METHOD of representing current-observations, as used in the Coast Survey.—A. D. Bache.—[Sketch 3, (A, No. 3.)]
1853	169	SANDY HOOK CHANGES.—[Sketch 8, (B, No. 3.)]
1855	164, 165	SANDY HOOK CHANGES.—(*See* NEW JERSEY, etc.)—A. M. Harrison.—[Sketch No. 9.]
1855	170-171	REMARKS BY MR. BOSCHE ON SURVEYS made at different periods in New York Harbor.
1856	263-264	TIDAL CURRENTS AT SANDY HOOK.—Notes on the causes of northwardly increase of the peninsula.—A. D. Bache.—[Errata, p. 264: 1856, p. XX.)
1856	264-266	NEW YORK HARBOR AND DEPENDENCIES.—H. Mitchell.—On tidal and current observations made in New York Harbor, city docks, Newark Bay, and the Kills.
1858	197-203	NEW YORK BAY AND SANDY HOOK.—A. D. Bache.—On the character of the tidal currents in the vicinity of the bar: 1, normal currents at the entrance to New York Bay; 2, False Hook Channel and the approaches; 3, currents of Sandy Hook Bay.—Table I to IV, lunar time, duration, velocity, and direction of currents; V and VI, velocities corrected for diurnal and half-monthly inequalities.—[Sketch 39.]
1857	358-373	NEW YORK HARBOR; report of advisory council.—Physical causes of changes: 1, changes at Sandy Hook; 2, northern side of entrance, Coney Island and south shore of Long Island; 3, New York bar; 4, New York Upper Bay; 5, Newark Bay; 6, Hudson River; 7, East River to Throg's Neck; statistic extracts.—[Errata, p. 272: 1858, p. XX.]
1858	204-207	EAST RIVER AND NEW YORK BAY.—H. Mitchell.—On the observations of surface and sub currents.
1859	311-317	NEW YORK HARBOR.—H. Mitchell.—On its physical survey, with description of apparatus for observing the currents.—[Sketch 40.]—[Errata, p. 317: 1860, p. XX.]
1856	266-267	HUDSON RIVER.—G. Würdemann.—On tidal observations made between Albany and New York City.—[Sketch 6.]
1851	482-484	BEAUFORT HARBOR, NORTH CAROLINA.—H. L. Whiting.—Operative causes of its physical permanency.—[Sketch 17, (D, No. 5.)]
1854	*21-*23	BEAUFORT HARBOR, NORTH CAROLINA.—J. N. Maffit.—Its capacity, changes, and improvements.—[Sketch 23.]
1857	152-153	BEAUFORT HARBOR, NORTH CAROLINA.—C. R. P. Rodgers.—Present condition of bar and anchorage.—[Sketches 29 and 30.]
1864	57	BEAUFORT HARBOR.—E. Cordell.—Development of changes at the bar and in the channel.—[Sketch 26.]
1857	153-155	CAPE FEAR ENTRANCES, NORTH CAROLINA.—J. N. Maffit.—Elements of physical changes wrought.—[Sketch 33; also, 1855, Sketch 16]
1858	150-151	CAPE FEAR ENTRANCES.—T. B. Huger.—Recent changes in its hydrography.—[Sketches 12 and 13.]
1865	45	ENTRANCE TO CAPE FEAR RIVER, NORTH CAROLINA.—J. S. Bradford.—Hydrographic changes.—[Sketch 13.]
1851	488-494	FLORIDA COAST RECONNAISSANCE.—F. H. Gerdes.—A, description; B, survey; C, tides and currents; D, railroad across the peninsula; E, light-houses and buoys; F, general remarks on Cedar Keys Harbor.—[Sketches 27, 28, and 29.]
1851	528-530	SAN DIEGO RIVER ENTRANCE.—[Sketches 6 and 7.]—(*See* C, statistics; *a*, coast, western.)

GULF STREAM.

1853	46-51	(Report.)—[Sketches 15 and 16.]—Gulf Stream explorations.
1860	165-176	GULF STREAM.—A. D. Bache.—General account of the methods used in developing its hydrography, and summary of results obtained; 1, instruments for temperatures; for depth; for obtaining specimens of the bottom; 2, plan of the work; 3, method of discussion of results; 4, results; type-curves of law of temperature with depth at the most characteristic positions; type-curves of law of distribution of temperature across the stream; curves of depths of equal temperatures.—Table I, distance of the cold wall from the shore, and widths of the several bands of cold and warm water of the Gulf Stream, measured on the lines of the sections; 5, limit of accuracy of the determinations; II, probable uncertainty in the determination of maximum and minimum points by running the same sections over in different years, by different observers; III, value of probable error of determination of the bands for each section and the average of the whole; 6, figure of the bottom of the sea below the Gulf Stream; 7, general features of the Gulf Stream.—[Sketches 19 to 22.]
1858	217-222	FLORIDA GULF STREAM.—E. B. Hunt.—Notices of certain anomalies; changes of current depending upon the winds and seasons.
1854	*156-*161	GULF-STREAM TEMPERATURES.—A. D. Bache.—On the distribution of temperatures on and near the Gulf Stream: 1, at different depths; 2, at the same depths on sections across the axis of the Gulf Stream.—Table I, probable uncertainty in determination of the maximum and minimum points; 3, connection of the figure of the sea-bottom with the distribution of temperature; 4, the "cold wall;" 5, reference to shifting; 6, chart of Gulf Stream.—[Sketches 24 and 25.]—[Errata, p. 158, 159, 160: 1855, XIX.]
1855	53-55	GULF STREAM EXPLORATION.—Programme, Craven's Cape Florida section; Sands's soundings along the Gulf Stream axis; depths; bottom-configuration, temperatures, and bottoms.
1855	359	BOTTLE-PAPER.—Current-bottle card thrown over near Sandy Hook and picked up at the bar at Santa Cruz, one of the Western Islands.
1855	84	(Report.)—[Gulf Stream deep-sea soundings.—[Sketch 38, (H, No. 3.)]
1859	306-310	GULF STREAM; distribution of temperature in the water of the Florida channel and straits.—A. D. Bache.—Form of bottom; change of temperature with depth; temperature in a direction across the stream; bands of warm and cold water; the "cold wall;" longitudinal section; effects of pressure on Saxton's deep-sea thermometer, under pressure and free from pressure; thermometers Nos. 5 and 10.—[Sketch 35.]
1868	166, 167	NOTE ON GULF-STREAM OBSERVATIONS.—H. Mitchell.—Decrease of bottom-temperature in still-water channels.—(Sequel to 1867, p. 179, below.)

PHYSICAL HYDROGRAPHY—GULF STREAM—Continued.

Year.	Pages.	Title of papers.
1866	35-44	FLORIDA STRAITS.—H. Mitchell.—Report on soundings; northern approach; southern approach; difficulties in the way of laying a telegraph-cable; remarks upon lines and leads; table of soundings across the Straits of Florida, from Sand Key to El Moro, 1866.—[Sketch 17.]
1866	139	Supplement, p. 139; diagram of rates of outrun of line, Berryman apparatus.
1867	176-179	SOUNDINGS IN THE GULF STREAM BETWEEN KEY WEST (FLORIDA) AND HAVANA.—H. Mitchell.—Table I, soundings in the Gulf Stream near the coast of Cuba, 1867; II, current observations.—[Sketch 25.]—(Supplement, 1868, pp. 166-167.)
1853	*82-*83	EXAMINATION OF SPECIMENS OF BOTTOM obtained in Gulf Stream.—L. F. Pourtales.
1855	360	GULF STREAM BOTTOMS.—J. W. Bailey.—On the characteristics of some bottoms from the Cape Florida Gulf Stream section.
1858	248-250	ANALYSIS, MICROSCOPICAL, of specimens of bottom taken in sounding.—L. F. Pourtales.—Green and ochraceous incrustation of *Foraminifera*, and jet tint of specimens.
1867	180-182	FAUNA OF THE GULF STREAM.—L. F. Pourtales.—Dredgings in the Straits of Florida.
1868	168-170	REPORT UPON DREDGINGS NEAR THE FLORIDA REEF.—L. F. Pourtales.—Organic specimens; corals, echinoderms, brachiopods, &c.
1869	208-219	REPORT UPON DEEP-SEA DREDGINGS IN THE GULF STREAM DURING THE THIRD CRUISE OF THE UNITED STATES STEAMER BIBB.—L. Agazziz.—Faunæ of the submarine zones; reef-zone; sedimentary zone; coral slope of living cretacean types; floor of foraminiferine mud; geological inferences; inclination of the reefs; pot-holes; formation of oölithic, amorphous, and compact limestones; the Jurassic submarine seam; embryology of corals and formation of colonies by disk-embranchment; extinct forms representing modern developmental transitions; lines to be dredged.
1869	220-225	THE GULF STREAM.—Characteristics of the Atlantic sea-bottom off the coast of the United States.—L. F. Pourtales.—Manner of dredging; siliceous formation; green-sand formation.
1858	228-246	DEEP-SEA SOUNDINGS.—W. P. Trowbridge.—Investigation of the laws of motion governing the descent of the weight and line; formulæ of velocity of descent.—Table I, rates of descent and resistance, in pounds, upon the sinker and line, with one and with two 32-pound shot, 0.07 of an inch in diameter; II, same, with 96 and 126 pound weights—deep-sea line; III, influence of different lengths of line moving with the same velocity; ratios of lengths to ratio of resistances; VII, comparison of resistances upon the same lengths of lines of different diameters, moving at the same velocity; VI, influence of lengths at different depths; VIII, same, continued; IX, rates of descent, velocity, resistance to sinker and line, and weight of line in water, from observations made by Jos. Dayman;—diameter of line, 2 inches; weight, 96 pounds; specific gravity, 1.3.—[Sketch 38.]—[Errata, p. 235: 1858, p. XXI.]
		TIDE-TABLES for navigators, with description of bench-marks, explanations, and examples for use.—A. D. Bache.
1853	*67-*70	
1854	*180-*189	[Errata, 181, 182, 183, 185: 1855, p. XX.]
1855	347-359	[Errata, 349, 351, 353, 354, 358: 1857, p. XVIII.]
1856	120-133	[Errata, 130: 1856, p. XX.]
1857	157-178	
1858	275-297	[Errata, 279: 1859, p. XVI.]
1859	136-167	[Errata, 145: 1860, p. XX.]
1860	131-164	[Errata, 161: 1860, p. XX.]
1861	98-131	
1862	93-126	
1863	84-117	
1864	58-90	
1866	47-49	Predictions for Eastport, as a specimen.

TERRESTRIAL MAGNETISM.

Year.	Pages.	Title of papers.
1856	226	MAGNETIC OBSERVATIONS.—C. A. Schott.—Methods used in his observations of the present year; magnet H.
1862	232-235	BESSEL'S PERIODIC FUNCTIONS developed for periods frequently occurring in magnetic and meteorological investigations; with examples.—C. A. Schott.
1864	205-206	GIRARD COLLEGE OBSERVATIONS.—Index to discussion by A. D. Bache.—(*See* Magnetic elements; discussed.)
1860	350-351	EASTPORT STATION, MAINE.—General description of magnetic station.—L. F. Pourtales.
1860	326-349	KEY WEST STATION.—Description of instruments and plan of magnetic observatory; with results.—W. P. Trowbridge.—Declinometer, recording cylinder, and clock; vertical-force magnetometer; adjustments; mean daily range of temperature for each month, 1851, 1852, and monthly range for four years; mean monthly temperature for fourteen years; lamps; scale-measurements; temperature co-efficients of the horizontal and vertical forces of magnets; photographic arrangements; magnet H—axis and intensity; dip; scale-values for intensity-magnets—tables and computation; experiments for temperature co-efficients of horizontal-force magnet, with hot water and ice.—[Sketches 23 and 24.]
1862	236-238	DIPPING-NEEDLE.—Description of a new form of axis, changeable in position.—J. E. Hilgard.
1854	*142-*145	(1844-'45.)—TABLE OF MAGNETIC DECLINATION.—G. W. Dean.—Results of Coast Survey magnetic observations at 136 stations along the coast of the United States.—[Errata, p 144, 145: 1855, p. XIX.]
1855	295-306	(1844-'55.)—TABLE OF MAGNETIC DECLINATION, in geographical order, from Coast Survey observations; with notes by A. D. Bache and J. E. Hilgard.—Discussion of magnetic declination: 1, northern part of Gulf of Mexico; 2, Atlantic coast; 3. Pacific coast.—[Sketch 56.]

TERRESTRIAL MAGNETISM—Continued.

Year.	Pages.	Title of papers.
1859	172-175	(1858.)—VARIATION OF THE COMPASS.—General table for the use of navigators.—[Sketch 38.]
1865	174-176	(1865.)—REPORT on the distribution of the magnetic declination on the coast and parts of the interior of the United States.—C. A. Schott.—Isogonic chart for 1870.—[Sketches 27 and 28.]
1855	306-337	(1717-1855.)—SECULAR VARIATION OF MAGNETIC DECLINATIONS.—C. A. Schott.—Discussion of the secular change in the magnetic declinations on the Atlantic and part of the Gulf coasts of the United States.—Providence, R. I.; Hatborough, Pa.; Philadelphia, Pa.; Boston, Mass.; Cambridge, Mass.; New Haven, Conn.; New York, N. Y.; Charleston, S. C.; Mobile, Ala.; Havana, Cuba; Burlington, Vt.; Chesterfield, N. H.; Salem, Mass.; Nantucket, Mass.; Albany, N. Y.; Washington, D. C.; Pensacola, Fla.—[Sketch 51.]—[Errata, p. 314, 335: 1855, p. XVIII.]
1856	228-235	(1792-1855.)—SECULAR CHANGE OF DECLINATION; Western coast.—C. A. Schott.—List of magnetic declinations observed on the western coast from the earliest to the present ones, arranged in order of geographical latitudes.—Annual change: 1, San Diego; 2, Monterey; 3, San Francisco; 4, Cape Mendocino; 5, Cape Disappointment.—Recapitulation of results for secular change.
1870	111-114	RESULTS of observations for *daily variation* of the magnetic declination, made at Fort Steilacoom, Washington Territory, in 1866, and at Camp Date Creek, Arizona, in 1867, by David Walker, acting assistant surgeon U. S. A., and discussed and reported by Assistant Charles A. Schott.
1858	192-195	(1680-1850.)—SECULAR VARIATION OF MAGNETIC DECLINATION AT HATBOROUGH, PA.—C. A. Schott.—Discussion and development of an intermediate period.—Table of declinations from 1680 to 1850.—Diagram.—[Errata, p. 193: 1858, p. XXI.]
1858	195-197	(1809-1857.)—SECULAR VARIATION AT WASHINGTON, D. C.—C. A. Schott.—Declination from 1809 to 1857.—Dip from 1839 to 1858.
1870	107-110	New investigation of the secular changes in the *declination, dip and intensity* of the magnetic force at Washington, D. C.—By Assistant Charles A. Schott.
1859	296-305	(1680-1860.)—SECULAR CHANGE IN DECLINATION.—C. A. Schott.—Variation of the needle on the coasts of the United States for every tenth year since 1680; formulas expressing secular change, used for calculating the tabular values for Group I, stations between Portland, Me., and Williamsburgh, Va., with table of observations made between 1680 and 1860; for Group II, southern stations and western coast.—Record of all observed declinations made use of in the above paper, not heretofore published in the Coast Survey Reports.
1861	251-256	New discussion of the distribution of the magnetic declination on the coast of the Gulf of Mexico, with a chart of the isogonic curves, for 1860.—By Assistant Charles A. Schott.
1861	256-259	New discussion of the distribution of the magnetic declination on the coast of Virginia, South Carolina, and Georgia, with a chart of the isogonic curves, for 1860.—By Assistant Charles A. Schott.
1856	235-245	(1780-1855.)—SECULAR CHANGE OF INCLINATION; Atlantic coast.—C. A. Schott.—Toronto, Canada; Albany and Greenbush, N. Y.; Cambridge, Mass.; Providence, R. I.; West Point and Cold Spring, N. Y.; New Haven, Conn.; New York, N. Y.; Philadelphia, Pa.; Washington, D. C.; Baltimore, Md.; recapitulation of results.—Table I, geographical positions and number of dip-observations; II, formula for each station; III, probable error, epoch of minimum dip and annual variation in current year.—[Sketch 63.]
1856	246-249	(1790-1855.)—SECULAR CHANGE OF INCLINATION; Western coast.—Approximate determination of the secular change of inclination.—C. A. Schott.—Table of observations made up to the present time; deductions therefrom.—1, San Diego; 2, San Pedro; 5, Monterey; 6, San Francisco; 8, Fort Vancouver; 10, Cape Disappointment.
1857	334-342	MAGNETISM.—Gradual loss of magnetic momentum in the Coast Survey magnets.—C. A. Schott.—Account of magnets: S 8, C 32, C 9, D, C 6, H, and Smithsonian magnet used in 1855.—Table: recapitulation of values for magnets severally, and discussion.—[Sketch 68.]
1861	242-251	SECULAR CHANGE OF INTENSITY.—C. A. Schott.—Discussion of observations made on the Atlantic, Gulf, and Pacific coasts of the United States; intensity-statistics; notes; table of annual change for Atlantic and Pacific groups.
1864	207-210	(1832-'36.)—DECLINATION, DIP, AND INTENSITY, as derived from observations made by J. N. Nicollet in the Southern States.
1854	*37-*40	(1853-'54.)—Page 39: Reference to instruments used, &c., in California.—W. P. Trowbridge.
1855	337	(1855.)—MAGNETIC OBSERVATIONS.—C. A. Schott.—Results for declination, dip, and horizontal intensity, on sixteen eastern stations, July to September, 1855.
1856	227	(1856.)—MAGNETIC ELEMENTS.—C. A. Schott.—Results of his observations for declination, dip, and intensity at stations in Delaware, Maryland, and Virginia.
1858	191-192	(1856-1858.)—MAGNETIC ELEMENTS.—Continuation.
1859	296	(1859.)—DECLINATION, DIP, AND INTENSITY.—C. A. Schott.—Results of observations made by him in Canada, Maine, New Hampshire, Vermont, Massachusetts, and Connecticut.—Foot-note on disturbances.
1860	351-352	(1859; also, 1855.)—DECLINATION, DIP, AND INTENSITY at various stations; (supplementary to 1856, p. 227, and 1858, p. 191.)
1860	352	(1860.)—DECLINATION, DIP, AND INTENSITY, determined in 1860 on the coasts of Massachusetts, Long Island, and New Jersey.—C. A. Schott.
1862	230-231	(1860-1861.)—DECLINATION, DIP, AND INTENSITY at various stations; (supplementary to list, 1860, pp. 351-352.)
1863	204	(1863.)—DECLINATION, DIP, AND INTENSITY, from observations, by C. A. Schott and G. W. Dean, in Maine, Connecticut, and the District of Columbia—*discussed*.
1856	209-225	(1839-1855.)—TERRESTRIAL MAGNETISM.—Discussion relative to its distribution in the United States.—A. D. Bache and J. E. Hilgard.—Methods and sources used; corrections for secular variations; construction of maps, (Sketches 61 and 62;) comparison of maps for declination, dip, and intensity; supplementary note, (Mexican observations;) Table I, Atlantic, Gulf, and Pacific sections; II, near parallel 35°, by J. C. Ives, Whipple's expedition; III, from various new sources—lakes, territories, Panama; IV, residual difference between the Coast Survey observations, reduced to 1850, and the values obtained from the accompanying map.—[Sketches 61 and 62.]

TERRESTRIAL MAGNETISM—Continued.

Year.	Pages.	Title of papers.
1862	212–229	(1834–1862.) MAGNETIC SURVEY of Pennsylvania and parts of adjacent States from 1834 to 1862.—Discussion by A. D. Bache.—Declinations observed by him in 1840 and 1841; tabular comparison of secular changes in 1840, 1841, and 1862; chronometric results for longitude; geographical positions; distribution of declination for 1842.0; general table of results referred to common epoch, 1842.0; comparison of observed and computed values; dip, distribution of, and isoclinal lines for 1842, groups 1 to 4; correction to epoch; comparison of observed and computed dip; horizontal intensity and isodynamic lines for 1842; tabular formation of groups for the analytical expression of the distribution of horizontal force referred to 1842.0; comparison of observed and hypothetical computed values; representation of the total force.—[Sketch 47.]
		GIRARD COLLEGE observations, 1840 to 1845. Index of discussion, by A. D. Bache.
		Section I.—DECLINATION.
		PART I.—[Sketch 37.]—[Errata, p. 279, 280, 293: 1860, p. XX.]
1859	278	Introduction.
	279	Separation of disturbances and establishment of normal readings of the declinometer.
	285	Analytical expressions of the regular solar diurnal variation of the declination.
	286	Inequality of the amplitude due to the eleven (or ten) year period.
	287	Discussion of the number of disturbances of the declination; their annual inequality.
	290	Diurnal inequality of the number of disturbances of the declination.
	290	Deflections by disturbances; their mean annual amount; effect of the eleven (or ten) year period.
	292	Deflections by disturbances; their mean diurnal amount.
	295	Connection of the frequency of the solar spots with the changes in the amplitude of the diurnal variation of the declination.
		PART II.
1860	293	Investigation of the solar diurnal variation of the declination.
	302	Its semi-annual inequality.
	303	Analytical and graphical exhibition of the solar diurnal variation for each month, summer, winter, and year.
	307	Maxima and minima, and times of average value of the declination; diurnal range.
	309	Annual variation of the declination.
		PART III.
1860	312	Lunar influence on the magnetic declination; tabulation of results according to the moon's hour-angle.
	318	Comparison of lunar diurnal variation for three epochs.
	319	Resulting lunar diurnal variation.
	321	Inequality in the lunar diurnal variation.
	324	Investigation of deflections depending upon lunar phases; variation in declination and in parallax.
		Section II.—HORIZONTAL FORCE.
		PART IV.—[Sketch 48.]—[Errata, p. 178, 182, 1862, p. IV.]
1862	161	Instrumental notice.
	162	Correction of readings for changes of temperature; scale-values.
	169	Correction for progressive instrumental change; hourly normals for each month.
	173	Horizontal intensity, absolute value; effect of the loss of magnetism of the bar; secular change.
	174	Separation of the larger disturbances.
	175	Corrected normals.
	178	Investigation of the eleven (or ten) year period, from changes in the amplitude of the solar diurnal variation.
	180	Eleven (or ten) year inequality, as indicated by the disturbances.
	182	Analysis of the disturbances; annual and diurnal variation.
	185	Classification of disturbances according to their magnitude.
		PART V.—[Sketch 48.]
1862	186	Preparation of hourly normals for each month.
	193	Regular solar diurnal variation.
	194	Semi-annual inequality in the diurnal variation.
	195	Analysis of the solar diurnal variation.
	198	Epochs of maxima and minima; amplitude; epochs of average value.
	200	Annual variation of the force.
		PART VI.
1862	202	Number of observations for lunar discussion and their distribution according to western and eastern hour-angles of the moon; differences from monthly normals, arranged for moon's hour-angles.
	206	Lunar diurnal variation for two periods.
	207	Lunar diurnal variation in summer and winter.
	209	Analysis of the lunar diurnal variation.
	210	Investigation of the horizontal force in reference to lunar phases.
	211	Influence of the moon's changes of declination.
	212	Influence of the moon's changes of parallax.

TERRESTRIAL MAGNETISM—Continued.

Year.	Pages.	Title of papers.
		Section III.—VERTICAL FORCE.
		PART VII.—[Sketch 30.]
1863	156	Instrumental notice.
	157	Determination of the effect of changes of temperature; scale-values; reduction of observations to a uniform temperature.
	164	Recognition and separation of the larger disturbances.
	168	Investigation of the eleven (or ten) year period, in the amplitude of the diurnal variation.
	171	Investigation of the eleven (or ten) year period in the disturbances, and their general analysis.
	172	Annual inequality in the number and amount of disturbances.
	174	Diurnal inequality of the disturbances.
	177	Classification of the disturbances according to their magnitude.
	178–183	Appendix: effect of the aurora borealis on the declination, the horizontal and vertical force.
		PART VIII.—[Sketch 30.]
1863	183	Preparation of hourly normals for each month and year.
	189	Regular solar diurnal variation.
	190	Semi-annual inequality of the diurnal variation.
	190	Analysis of the diurnal variation.
	193	Maxima and minima; ranges; epochs of average force.
	195	Annual inequality of the vertical force.
		PART IX.
1863	196	Number of observations for lunar discussion; distribution according to eastern and western hour-angles; differences from monthly normals, arranged for moon's hour-angles.
	201	Lunar diurnal variation in summer and winter.
	202	Analysis of the lunar diurnal variation of the vertical force.
	204	Lunar effect upon inclination and total force.
		Section IV.—DIP AND TOTAL FORCE.
		PART X.
1864	183	Formation of table of disturbances of the two component parts and their combination for dip and total force.
	184	Analysis of disturbances of the inclination.
	185	Their annual inequality in amount and number; eleven (or ten) year inequality.
	186	Diurnal inequality, in amount and number.
	187	Classification of disturbances in dip, according to their magnitude.
	187	Analysis of disturbances of the total force.
	188	Their annual inequality, in amount and number; eleven (or ten) year inequality.
	189	Diurnal inequality, in amount and number.
	190	Classification of disturbances in total force.
		PART XI.—[Sketch 38.]
1864	193	Combination of the diurnal normals of the two components for dip and total force.
	193	Solar diurnal variation of the inclination.
	194	Its semi-annual inequality.
	194	Analysis of the solar diurnal variation of the dip.
	195	Maxima and minima; ranges and epochs of average value.
	196	Solar diurnal variation of the total force.
	196	Its semi-annual inequality.
	197	Analysis of the solar diurnal variation of the total force.
	198	Annual inequality of the dip and total force.
		PART XII.
1864	199	Discussion of the magnetic inclination; introductory notice.
	200	Abstract of observations of dip; monthly means.
	203	Collection of dip-observations at Philadelphia.
	203–204	Analytical expression of secular change of dip-normal; absolute values of the magnetic declination, dip, horizontal, vertical, and total force for five epochs, and the mean epoch, January, 1843.
1865	166–174	(1860–1864.)—RESULTS of magnetic observations made at Eastport, Me., between 1860 and 1864.—Declination; diurnal range of; annual inequality, (diagram;) epochs of greatest diurnal deflection; mean monthly values of declination between August, 1860, and July, 1864; annual effect of the secular change; annual inequality of the declination; same at Toronto; comparative curve.--[Sketch 29, (theodolite magnetometer.)]
1869	199–207	(1867–1869.)—REPORT on the results from the observations made at the magnetic observatory on Capitol Hill, Washington, D. C., between 1867 and 1869.—C. A. Schott.—Magnetic instruments; scheme of observing; instrumental constants; results; declination on Capitol Hill; turning-epochs; dip; horizontal force; tabular synopsis of magnetic elements observed in the District of Columbia.

TERRESTRIAL MAGNETISM—Continued.

Year.	Pages.	Title of papers.
		Other influences:
1860	269–274	(1860.)—ECLIPSE at Anleziavik; suspension of vibrations during totality.
1854	*146	MERIDIAN-LINES.—Report of Assistant G. W. Dean on the establishment of meridian-lines at Petersburgh, Va., and Raleigh and Wilmington, N. C.
1860	324–326	SOLAR SPOTS.—Report of Assistant C. A. Schott on the results of observations made during the first seven months of the year 1860.
1861	259–261	SOLAR SPOTS.—Abstract of observations made at the Coast Survey Office, by C. A. Schott.
1862	231–232	SOLAR SPOTS.—Abstract of observations made at the Coast Survey Office, by C. A. Schott, supplementary to the preceding report.
1863	205	INDUCTION-TIME IN RELAY-MAGNETS.—Report on experments made by Assistant G. W. Dean, to determine their relative power.
1864	211–220	EDUCTION-TIME OF RELAY-MAGNETS, deduced from experiments.—By Assistant G. W. Dean.

DRAWING, ENGRAVING, AND ELECTROTYPING.

Year.	Pages.	Title of papers.
1853	*96–*163	TABLES FOR PROJECTING MAPS, with notes on map-projections.—C. A. Schott and E. B. Hunt.—Map-projections classified and defined; Bonne's or modified Flamstead's projection; the polyconic, its properties and varieties; formulas used for the computation of projection-tables in use at the Coast Survey Office; graphic construction of polyconic projections—Coast Survey methods; rectangular polyconic method; Table I, relation between the measures of length used in different countries; II, for converting (A) meters into statute miles; (B,) statute miles into meters; (C,) meters into yards; (D,) yards into meters; (E,) yards into miles; III, length of a degree of the meridian in nautical and statute miles for each fifth degree of latitude between 20° and 50°; IV, (A,) length of a degree of longitude between the parallels of 17° and 50°, for each degree of latitude, expressed in nautical miles; (B,) length of a degree of longitude between the parallels of 17° and 50° for each degree of latitude, expressed in statute miles; V, (A,) length in meters of 1° of latitude and longitude for each degree of latitude between 17° and 50°; (B,) co-ordinates of curvature for each degree of longitude from 1° to 35°, between latitudes 17° and 50°; VI, projection-tables, giving latitude and longitude arcs, and co-ordinates of curvature, from latitude 24° to 50°.—[Errata, *96, *97, *98, *102, *134: 1853, p. 182; Errata, *101, *113, *114, *115, *116, *130, *159: 1854, p. XII; Errata, *132, *137: 1856, p. XX.]
1856	296–307	PROJECTION-TABLES.—J. E. Hilgard.—Tables applicable to the projection of maps of large extent and minimum distortion in represented area; method; earth's dimensions; Table I, of co-ordinates for projecting the points of intersection of meridians and parallels; II, length, in meters, of one degree of latitude and longitude from latitude 20° to 54°; values of the corresponding radii of the developed parallel, and angles at each pole for 10° of longitude; III, tables for converting measures, (A,) of meters into statute miles; (B,) of statute miles into meters; (C,) of meters into yards; (D,) of yards into meters; (E,) of yards into miles; IV, length of a degree of the meridian in nautical and statute miles for each fifth degree of latitude between 20° and 50°; V, length of a degree of longitude for each degree of latitude from 19° to 54°, expressed in nautical and statute miles; VI, radii and polyconic development of a sphere with radius = 1.
1859	328–358	PROJECTION-TABLES for maps of large extent.—J. E. Hilgard.—Table I, length in meters of 1° of latitude and longitude, values of the corresponding radii of the developed parallel, and angles at each pole for 10° of longitude; II, co-ordinates of curvature.
1865	176–186	PROJECTION-TABLES for a map of North America.—Diagram; table of lengths, in meters, of 5° of latitude on the straight meridian; table of the radii of the parallels, and 5° of longitude on each parallel; I, table of co-ordinates, latitude 5° to 85°; II, co-ordinates of curvatures, latitude 55° to 89°; III, length, in meters, of 1° of latitude and longitude 55° to 89°.
1860	216–229	TOPOGRAPHICAL AND HYDROGRAPHICAL DELINEATIONS.—H. L. Whiting.—On the contouring and reduction of maps; on the scale of shades, and on the application of photography in preparing details for the engraver; 1, generalization of contour and other natural features for reduction to 1-80,000 contour; salt-marsh; sand-beaches and sand-hills; woods; fresh marsh; shore-line; low water; 2, hydrographic reductions; 3, reductions by photography; 4, scale of shades; report of E. Hergesheimer.
1863	206–207	HARRISON GLOBE-LENS.—J. E. Hilgard.—On tests made at the Coast Survey Office.
1860	398–399	DIVIDERS FOR TIDAL CURVES.—Description of form invented by J. R. Gillis, for graphical decomposition. [Sketch 40.]
1861	180–181	DRAWING-PAPER.—Results of experiments made on the relative expansion and contraction, under atmospheric changes, of parchment paper and backed antiquarian paper.—[Sketch 31.]
1862	255	DRAWING-PAPER tested with reference to expansion and contraction under atmospheric changes.
1852	108–111	ON LITHOGRAPHIC-TRANSFER PRINTING.—J. J. Stevens.
1853	*90–*93	NOTES ON LITHOGRAPHY and lithographic transfer.—E. B. Hunt.
1854	*201–*212	ART AND PRACTICE OF ENGRAVING.—E. B. Hunt.—Coast Survey engraving; its office, organization, and history.—[Errata, p. 204; *see* Index of errata.]
1867	55–56	THE PANTOGRAPH; its use in engraving.—E. Hergesheimer.—[Sketch 27.]
1854	*54–*57	ON ELECTROTYPE OPERATIONS AND CHEMIGLYPHIC EXPERIMENTS.—G. Mathiot.
1851	541–553	ELECTROTYPING OPERATIONS OF THE COAST SURVEY.—G. Mathiot.—Adhesion of deposit to matrix; actions in the electrolytic solution; laboratory apparatus; manipulation.—[Sketch 58.]
1854	*193–*201	MATHIOT'S SELF-SUSTAINING BATTERY.—G. Mathiot.—Its principles and workings.—[Errata, p. 194, 198: 1855, p. XIX.]
1855	366–368	GALVANIC EXPERIMENT.—G. Mathiot.—Time required to produce the maximum intensity of a voltaic current.
1855	369	ELECTROTYPE ART.—G. Mathiot.—Improved method for joining detached plates by electrotyping.
1855	370–373	MATHIOT'S BRANCH CIRCUIT GALVANOMETER.—G. Mathiot.—On a method of measuring galvanic currents of great quantity.

DRAWING, ENGRAVING, AND ELECTROTYPING—Continued.

Year.	Pages.	Title of papers.
1856..	316–317	ELECTROTYPES.—G. Mathiot.—On the result of experiments made in printing from thin plates.
1866..	130–138	ELECTROTYPING OPERATIONS.—G. Mathiot.—Historical; adhesion of deposit to matrix; time and expense of electro-casting; actions in the electrolytic solution; laboratory apparatus; manipulation.

MISCELLANEOUS, TECHNICAL, AND OTHER SUBJECTS.

Year.	Pages.	Title of papers.
1851 1866	145–160 120–130	FLORIDA REEFS, KEYS, AND COAST.—L. Agassiz.—Topography of Florida; mode of formation of the reef; animal life; the keys; coral reefs; ship-channel; the main-land; coast survey; physical changes in the Gulf Stream; changes in ages to come.
1853	*50–*51	CLIMATE, SOIL, AND GENERAL CHARACTER OF FLORIDA KEYS.—J. Totten.
1862	241–248.	FLORIDA REEF: its origin, growth, substructure, and chronology. By Capt. E. B. Hunt, U. S. Eng'rs.
1855	342–346	EARTHQUAKE-WAVE, PACIFIC OCEAN.—A. D. Bache.—Notice of earthquake-waves on the western coast of the United States, December 23 and 25, 1854; computation of ocean depth.—[Sketch 50, (J, No. 9.)]—[Errata, p. 342, 345: 1855, p. XVIII.]
1862	238–241	EARTHQUAKE-WAVES.—A. D. Bache.—Reprint of a paper deducing the depth of the Pacific Ocean from the effect of the Simoda earthquake on the tide-gauges in California and Oregon in 1854.—[Sketch 50.]
1869	233–234	ABSTRACT of a paper read before the National Academy of Sciences, April 16, 1869, on the earthquake-wave of August 18, 1868; wave-table.—J. E. Hilgard.
1868	243–259	GEOGRAPHICAL NAMES on the coast of Maine.—Ed. Ballard.
1858	251–270	FOREIGN GEODETIC SURVEYS.—W. P. Trowbridge.—Review showing their cost and progress, and other data, for comparison with the results of the United States Coast Survey; trigonometrical surveys of England, Ireland, and Scotland; hydrography of England; analysis of the report of the select committee appointed to consider the ordnance survey of Scotland, &c., 1856; France; India; Russia; Prussia; table of statistics of topographical maps in Europe; recapitulation; marine disasters—United States vessels, 1855, 1856, and 1857; imports, exports, tonnage, &c.; Great Britain, 1852 to 1855; Gulf of Mexico shipping; Florida reef.
1858	270–273	PROGRESS OF THE UNITED STATES COAST SURVEY.—W. P. Trowbridge.—Ratio of results for consecutive periods of twelve years.
1870	180–181	On the probable effect of extended piers in modifying the channel-facilities of San Francisco Bay, near Yerba Buena Island.—By Assistant Henry Mitchell.
1870	98–99	Extract from a report relative to a method of determining elevations along the course of a tidal river, without the aid of a leveling-instrument, by setting up graduated staves at such distances apart that the slacks of the tidal currents extend from one to another.—Rule: the difference in the elevations of the zeros of the gauges is equal to one-half the sum of the differences of their readings at the two slack waters.—By Assistant Henry Mitchell.
1868	260–277	CONDENSED ACCOUNT OF M. HELLERT'S EXPLORATIONS on the Isthmus of Panama; including his special explorations on the Isthmus of Darien, with suggestions for conducting a future survey.—G. Davidson.—Explorations; plan for exploration of the river Darien; outfit and duties of engineers; instrumental outfit; use of the heliotrope for communicating messages; form of record of levelings, courses, and distances; rod for leveling, distance, and station-mark for courses; to pack, unpack, and refill steel barometer; methods of ascertaining the discharge of water in any stream.
1860	399–402	LABRADOR EXPEDITION.—A. Murray.—Report of a voyage of steamer Bibb, and remarks on the winds and tides, &c.—(*See* Longitude by eclipse.)
1860	402–408	GEOLOGY OF THE COAST OF LABRADOR.—Notes by O. M. Lieber.
1867	281–290	ALASKA TERRITORY, GEOLOGY OF.—Th. A. Blake.—Ibid.
1867	299–317	ALASKA TERRITORY, METEOROLOGY OF.—A. Kellog.
1870	182–189	On the phosphate beds of South Carolina.—By Prof. N. S. Shaler.
1867	183–186	GEOLOGICAL AND ZOOLOGICAL RESEARCHES; their relation and general interests in the development of coast-features.—L. Agassiz.—(*See, also,* Coasts.)
1867	290–292	ZOOLOGY OF ALASKA TERRITORY.—W. G. W. Harford.
1867	318–324	BOTANY OF ALASKA TERRITORY.—A. Kellog.
1867	293–298	VOCABULARIES of the Kodiac, Unalaska, Kenai, and Sitka languages.
1867	325–329	VOCABULARY, Alaskan.
1856	319–322	ANNALS OF DISCOVERY ON THE ATLANTIC COAST.—J. G. Kohl.—Abstract of a history of the progress of discovery on the Atlantic coast of the United States.
1856	322–324	ANNALS OF DISCOVERY, GULF OF MEXICO.—J. G. Kohl.—Abstract of a memoir on the discovery and geographical development of the shores of the Gulf of Mexico within the limits of the United States.
1857	414–433	WESTERN COAST ANNALS of maritime discovery and exploration.—J. G. Kohl.—Report of the method and scope of a memoir on.
1855	374–375	ABSTRACT of a complete historical account of the progress of discovery on the western coast of the United States from the earliest period; compiled, under the direction of the Superintendent, by Dr. J. G. Kohl.
1864	220–222	TRAJECTORY OF RICOCHET-SHOT, notes on.—C. A. Schott.
1864	223	RANGES OF SHOT from heavy ordnance, remarks on.—C. A. Schott.
1856	335–340	COAST SURVEY STEAMER HETZEL.—Report on cause of boiler-explosion.—[Sketch 67.]
1857	404–414	INDEX OF SCIENTIFIC REFERENCES.—E. B. Hunt.—Report on progress made toward completion.
1856	325–330	INDEX OF SCIENTIFIC REFERENCES.—E. B. Hunt.—On the plan adopted and progress made in its preparation.

MISCELLANEOUS, TECHNICAL, AND OTHER SUBJECTS—Continued.

Year.	Pages.	Title of papers.
1856	331-333	ABBREVIATIONS FOR SCIENTIFIC REFERENCES.—E. B Hunt.—Suggestions for securing uniformity of designation.
1863	207	TITLES OF SCIENTIFIC PAPERS.—By the late Maj. E. B. Hunt, U. S. Eng'rs.
1851	526-528	COLUMBIA RIVER COMMERCE.—W. A. Bartlett.
1851	528-530	TRINIDAD, HUMBOLDT, AND SAN DIEGO BAY.—A. D. Bache.—Changes of current, and sailing-directions for San Diego.—[Sketches 6 and 7.]
1855	376-398	BLAKE'S GEOLOGICAL REPORT, WESTERN COAST.—W. P. Blake.—Observations on the physical geography and geology of the coast of California, from Bodega Bay to San Diego; physical geography of the mountain-ranges adjoining the coast; geology of the principal bays and ports from Point Reyes to San Diego.—[Errata, p. 379, 380, 382, 387, 388, 392, 394, 395, 396: 1857, p. XVIII.]
1857	354-358	WINDS ON THE WESTERN COAST.—A. D. Bache.—Table for deducing from the three daily observations the mean of the day; quantities of wind; tables for Astoria, San Francisco, and San Diego, and special wind-statistics.—[Sketch 66.]
1867	187-329	ALASKA TERRITORY; coast-features and resources.—G. Davidson.—Directory of the coast, 226-264; list of geographical positions, 265-274; aids to navigation, 274-280.—Geology, by Theod. A. Blake, 281-290.—Zoology, by W. G. W. Harford, 290-292.—Vocabulary of the Kodiac, Unalaska, Kenai, and Sitka languages, 293-298.—Meteorology, 299-317.—Botany, by A. Kellogg, 318-324.—Alaskan vocabulary, 325-329.—[Sketches 21 to 23.]—[Errata, 289, 22 from bottom *read* Escholtz Bay.]
1853	*89	BOILER-INCRUSTATION.—J. Hewston, jr.—Analysis of two specimens of deposit from the boiler of the Coast Survey steamer Hetzel.
1854	*192	SEA-WATER ACTION ON METALS.—J. E. Hilgard.—On the action of sea-water on metals used in the construction of instruments, and on magnetic needles; Phenix disaster.—(*See, also,* Terrestrial magnetism.)—[Errata, p. *192, 5 from bottom, word 9, *read* presence.]
1856	317-318	ANALYSIS OF SEA-WATER.—Chemical analysis of the water of New York Harbor.—Wolcott Gibbs.
1856	318-319	ANALYSIS OF SEA-LAND.—Wolcott Gibbs.—Examination of specimens of sea-soil taken from the base-sites at Cape Florida and Cape Sable.
1851	136-137	CURRENT-NOTATIONS.
1855	193-200	COAST SURVEY SAILING-DIRECTIONS, CATALOGUE.
1851	530-531	ENTRANCE OF COLUMBIA RIVER TO ASTORIA, sailing-directions.—W. P. McArthur.
1858	297-458	DIRECTORY FOR THE PACIFIC COAST of the United States.—G. Davidson.—Sailing-directions; geographical positions; tide-establishments for San Francisco; rain-fall; temperatures; commerce; magnetics; meteorological observations in the Strait of Juan de Fuca, &c.; and geographical positions.—[Errata, p. 359, 381, 429, 442: 1858, p. XXI.]
1862	268-430	DIRECTORY FOR THE PACIFIC COAST OF THE UNITED STATES.—G. Davidson.—Introduction and explanatory remarks; Mexico; California; Oregon; Washington Territory and Vancouver's Island; British Columbia; Puget Sound.—Tide-tables for San Francisco, 311; commercial statistics; meteorological observations, Washington Territory, 416; geographical positions, 418; tide-tables for San Diego, 421; for Astoria, 424; for Port Townshend, 427;—of magnetic declination, 1863, 430.—[Errata, 272, 275, 285, 286, 288, 290, 292, 296, 297, 299, 301, 302, 303, 304, 307, 316, 323, 325, 327, 328, 329, 344, 355, 359, 360, 362, 363, 364, 365, 367, 370, 371, 376, 379, 383, 387, 389, 392, 396, 399, 402, 404, 408: 1866, p. 141.]

APPENDIX No. 18.

ERRATA FROM 1851 TO 1870.

ERRATA, 1851.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
11	......	8	reduced	recorded	1851
17	32	......	VI	VII	1851
33	4	......	Sebattis	Mount Independence	1851
34	......	11	Liverpool	Greenwich	1851
34	......	10	39.96	29.96	1851
36	21	......	Mason	Nason	1851
154	6	......	Macandrina	Mæandrina	1851
163	38	......	6356079.11	6356078.96	1853
168	......	......	Quaker, [longitude,] 57″.34	57″.32	1851
169	......	......	Pocasset, [latitude,] 07″.20	07″.23	1851
169	......	......	Pocasset, [latitude,] 11″.36	11″.33	1853
185	14	......	70° 05′ 36″.39	70° 05′ 36″.59	1854
189	3	......	Sursuit Creek, 41° 45′ 32″.29, 70° 08′ 07″.07	Sursuit Creek, 41° 45′ 30″.25, 70° 08′ 15″.94	1853
189	3	......	55° 49′ 44″, Scargo Hill 235° 48′ 11″	54° 49′ 44″, Scargo Hill 234° 48′ 11″	1853
189	3	......	3943.7, 4312.7, 2.45	3744.1, 4094.4, 2.33	1853
189	4	......	5799.3, 6341.9, 3.60	5588.6, 6111.5, 3.47	1853
189	12	......	10794.9, 11805.0, 6.71	108813.2, 11825.0, 6.72	1853
190	5	......	3815.6, 4172.6, 2.37	3849.6, 4209.8, 2.39	1853
190	6	......	87° 45′ 11″, West Chatham 267° 42′ 02″	87° 58′ 54″, West Chatham 267° 55′ 45″	1853
190	6	......	6546.4, 7159.0, 4.07	6567.8, 7182.3, 4.08	1853
191	23	......	6789.0, 7424.3, 4.22	6797.6, 7433.7, 4.22	1853
192	21	......	Latitude, 42° 03′ 02″.10	Latitude, 42° 03′ 02″.01	1855
194	11	......	70° 09′ 45″, Monk's Hill 250° 06′ 58″	318° 08′ 24″, Manomet 138° 10′ 55″	1853
194	16	......	224° 09′ 47″	264° 09′ 47″	1853
217	21	......	70° 37′ 44″.63	70° 37′ 04″.63	1853
218	6	......	53″.07	53″.04	1853
220	19	......	43° 38′ 02″.03, 70° 17′ 02″.33	43° 37′ 55″.59, 70° 16′ 49″.00	1853
220	19	......	218° 48′ 26″, Bramhall's Hill 38° 49′ 00″	207° 07′ 39″, Bramhall's Hill 27° 08′ 03″	1853
220	19	......	1758.5, 1923.1, 1.09	1763.2, 1928.2, 1.10	1853
225	21	......	Longitude, 71° 35′ 49″.74	71° 35′ 09″.74	1855
252	14	......	8.09 miles	5.85 miles	1854
252	15	......	1350.3, 1476.7, 0.84	13503.0, 14766.5, 8.39	1854
258	19	......	Sawpits	Port Chester	1853
258	20	......	Captain's Island	Little Captain's Island	1853
271	9	......	W. Hubbel	Uriah Hubbel	1853
276	17	......	Kakeout Hill	Kieckout Hill	1853
286	11	......	Aquackanonk	Acquackanonk	1853
286	14	......	Aquackanonk	Acquackanonk	1853
286	17	......	Aquackanonk	Acquackanonk	1853
286	19	......	Aquackanonk	Acquackanonk	1853
304	......	......	[Maulden's Mountain, latitude,] 12″.01	[Latitude,] 11″. 98	1851
324	9	......	76° 13′ 58″.50	76° 13″ 58″.30	1853
340	11	......	16° 52′ 54″; Harrison, 196° 52′ 32″	337° 37′ 30″; Harrison, 157° 37′ 46″	1855
340	12	......	337° 37′ 30″; Wilmer, 157° 37′ 46″	16° 52′ 54″; Wilmer, 196° 52′ 32″	1855
341	19	......	Longitude, 75° 57′ 42″.47	Longitude, 75° 57′ 52″.47	1855
342	3	......	Longitude, 75° 36′ 32″.11	Longitude, 75° 56′ 32″.11	1855
344	4	......	2479.3, 2711.1, 1.54	1969.4, 2153.7, 1.22	1855
346	12	......	Azimuth, 93° 34′ 20″	Azimuth 93° 34′ 00″	1855
360	21	......	38° 24′ 06″.56	38° 28′ 06″.56	1853
372	19	......	04″.86	04″.90	1853

ERRATA, 1851—Continued.

Page.	Line from— Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
374	15	......	76° 14′ 24″.22	76° 14′ 24″.33	1853
375	14	......	45″.55	44″.55	1853
378	19	......	75° 10′ 08″.51	75° 10′ 10″.51	1853
400	12	......	47° 54′ 14″	227° 54′ 14″	1853
400	13	......	294° 22′ 49″	294° 32′ 49″	1853
400	17	......	124° 49′ 48″; Jack Shoal, 304° 48′ 54″	94° 22′ 01″; Jack Shoal, 274° 21′ 13″	1853
400	18	......	168° 39′ 02″; New Inlet, North Point, 348° 38′ 47″	167° 38′ 20″; New Inlet, North Point, 347° 38′ 11″	1853
400	21	......	94° 22′ 01″; Jack Shoal, 274° 21′ 13″	124° 49′ 48″; Jack Shoal, 304° 48′ 54″	1853
400	22	......	167° 38′ 20″; New Inlet, North Point, 347° 38′ 11″	168° 39′ 02″; New Inlet, North Point, 348° 38′ 47″	1853
402	12	......	Little Hill, 52° 52′ 09″	Little Hill, 52° 42′ 09″	1853
404	17	......	11869.0, 12979.6, 7.38	6506.3, 7115.1, 4.04	1853
404	18	......	6506.3, 7115.1, 4.04	11869.0, 12979.6, 7.38	1853
409	17	......	81° 05′ 14″.32	81° 05′ 16″.85	1853
411	5, 6	......	......	Lines 5 and 6 from top to be struck out	1855
416	3	......	14678.7, 16052.2, 9.12	14613.6, 15981.0, 9.08	1853
416	4	......	181° 47′ 42″; Black Point, 1° 48′ 34″	181° 48′ 35″; Black Point, 1° 48′ 40″	1853
425	9	......	2376.1, 2598.3, 1.48	2576.1, 2817.1, 1.60	1853
480	33	......	4*h.* 44*m.* 29.05*s*	4*h.* 44*m.* 29.50*s.*	1853
553 } 558 }	......	......	......	The depth on Pot Rock was found, in subsequent survey by Major Frazer, to be 18 feet, and, after additional blasting, three points of 19 feet 3 inches remained, December, 1852.	1851

ERRATA, 1852.

Page.	Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
3	......	3	......	*Dele* "so"	1852
24	......	3	the	three	1852
28	......	7	position	portion	1852
34	2	......	N. N. W	S. S. E. ¾ E	1854
43	3	......		*Dele* "(Appendix No. 16.)"	1852
			l'Outre	Loutre, (*passim*)	1852
71	......	......	......	Appendix No. 1.—Change 1852-'53 in heading to 1851-'52.	1852
72	9	......	......	After "latitude" insert "longitude".	1852
78	25, 26	......	......	Transfer Lieutenants Doty and Huger to "office" part of list.	1852
82	3	......	......	After "Beaufort Harbor" insert "N. C."	1852
101	......	1	Tatersh	Talo'osh, (*passim*)	1852
104	......	17	Farralones	Farallones, (*passim*)	1852
104	......	13	Farralone	Farallon, (*passim*)	1852
105	3	......	Ana	Año	1852
105	......	14	Arquilla	Arguilla	1852
115	11	......	the phenomenon	these'	1852
119	......	25	depressed	decreased	1852
119	......	19	mark	mask	1852
121	......	8	......	Insert "and" before "E"	1852
121	......	......	......	[*Passim*,] for "A" read "(A)", and for "(E)" read "E".	1852
137	......	18	Eastern State	Eastern city	1852
137	......	18	Seacore	Secor	1852
139	......	17	Sedwick	Sedgwick	1852
148	......	16	Washington	Fort Washington	1852

ERRATA, 1853.

Page.	Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
			[List of geographical positions:]		
*15	12	......	electromagnet	electromagnetic	1854
*16 *et seq.*	}	......	[Heading of first column,] Name or station	Name of station	1854
*17	15	......	70° 49′ 50″.60	70° 49′ 50″.66	1854
*19	8	......	6608.5, 7226.9, 4.10	6808.5, 7445.6, 4.23	1855

ERRATA, 1853—Continued.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
			[List of geographical positions]—Continued.		
*20	27	......	15721.9, 17193.0, 9.77	15771.9, 17247.7, 9.80	1854
*28	20	......	119° 32′ 03″	199° 32′ 03″	1854
*29	......	14	1904.3	1964.3	1854
*31	40	......	3.93	3.98	1854
*32	5	......	Beaufort, commandant's house	Commandant's house	1854
*32	......	14	35° 05′ 38″.32	32° 05′ 38″.32	1854
*33	12	......	5319.2 yards	5379.2 yards	1854
*34	10	......	189° 25′ 15″	189° 25′ 15″	1854
*36	16	......	3.02 miles	8.02 miles	1854
*42	13	......	83551.1 yards	8355.1 yards	1854
*101	28	......	[Projection tables,] sin $\frac{1}{2}$ θ 30n sin L sin 1″	$\frac{1}{2}$ θ = 30n sin L sin 1″	1854
*101	......	......	[Throughout page,] x, y	X, Y	1854
*113	......	15	[Column 60″,] 1885.47	1685.47	1854
*113	......	5	[Column 60″,] 16—3.21	1683.21	1854
*114	17	......	[Column 10″,] 9.9	279.9	1854
*115	5	......	1′	1″	1854
*116	5	......	[Column 20″,] 256.1	556.1	1854
*130	......	5	[Column 7″,] 0.8	180.8	1854
*132	......	5	[Column 50″,] 1266.4	1276.4	1857
*134	5	......	Minutes of longitude, 1″	Minutes of longitude, 1′	1853
*137	......	5	[Column 50″,] 1237.5	1237.2	1857
*159	4	......	10	10″	1854

ERRATA, 1854.

9	27	......	Appendix No. 7	Appendix No. 43	1854
34	......	15	De Barres	Des Barres	1854
35	19	......	uncertainty	indefinite	1854
36	16	......	Succunnesset	Succonesset	1854
36	......	3	Sketch No. 26	Sketch No. 34	1854
40	9	......	sites	sights	1855
40	......	20	Barley's	Baily's	1854
40	......	1	6280	6293	1855
41	2	......	improves	impairs	1855
43	14	......	Versalins	Vervalins	1854
49	3	......	New Point Comfort	New Port News	1854
			IN APPENDICES.		
*19	{12, 13, 14}	......	......	At very low water of spring-tides	1855
*27	27	......	Kays	Cayo	1855
*51	......	......	[List No. 2, No. 56,] 1-10000	1-80000	1855
*52	......	......	[List No. 3, No. 21,] 1-30000	1-20000	1855
*53	......	......	[List No. 5, No. 15,] 1-30000	1-20000	1855
*65	6	......	Sin C. Agamenticus	m	1855
*65	7	......	Ag	Unk	1855
*65	8	......	Unkonoonsic	Thompson	1855
*65	9	......	m	Sin C. Thompson	1855
*70	6	......	9.905	9.925	1855
*70	......	22	are equally	are nearly equally	1855
*72	10	......	x, B	x, — B.	1855
*72	......	16	$p^{'''}_{'''} m^{'''}_{'''}$	$p^{'''}_{''} m^{'''}_{''}$	1855
*75	17	......	= + [x n 1]	= − [x n]	1855
*78	4	......	5	+ 5	1855
*79	......	1	but may	but the accuracy may	1855

ERRATA, 1854—Continued.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
*91		4	[Third column,] 0.9	0.0	1855
*94	23		0.667	0.067	1855
*102		4	+ 102. 0	+ 105.0	1855
*112	4		0″.061, 0″.105	0s.061, 0s.105	1855
*112	12		0″.104	0s.104	1855
*112	22		0″.139	0s.139	1855
*112		24	2″.734	2s.734	1855
*114	12		according	recording	1855
*115	24		5h. 8m. 29s	5h. 8m. 11s	1855
*117	10		L	L^1	1855
*131	6		Germany and	Germany	1854
*131	8			Cambridge (England) and Greenwich, and Greenwich and Brussels.	1854
*131 et seq.			[*Passim*,] χ, N, n, t, E	x, N, n, t, ϵ	1854
*131		1	χ^s	x^s	1854
*132	4			$\int_x^\infty e - \frac{1}{2}x$	1854
*132				Expression "(D)" should read "$R = e^{\frac{1}{2}(x^2-1)}\psi x$"	1854
*132		20	third contain	the third contains	1854
*132		15	only in very rare cases	in very rare cases only	1854
*133	6, 7		(A. J., II, 162)	(Ast. Jour., II, 162)	1854
*133	25		reliable	trustworthy	1854
*133		23		$\int_0^t \frac{2e^{-t^2}dt}{\sqrt{\pi}}$	1854
*133		21	e^{t2} and e^{-t2}	e^{t^2} and e^{-t^2}	1854
*133		12	β	B	1854
*133		9	semi-diameter	semi-diameter of Venus	1854
*134	22		8.522	9.522	1854
*134		12	1.015	1.007	1855
*135			[Opposite 22, in first column,] 5.066	5.068	1854
*136		4	[Column 7,] −3.361	3.360	1854
*140	2		$a = \frac{u_4 - u_2 - \frac{1}{2}b(t'' + t')}{t''}$	$a = \frac{u_4 - u_3}{t''} - \frac{1}{2}b(t'' + t')$	1855
*144		20	7 36.7	1 36.7	1855
*144		19	7 39.6	1 39.6	1855
*144		18	2 05.9	2 01.9	1855
*145	6		2 11.3	1 11.3	1855
*145	16		35 51.8	35 47.5	1855
*145	16		75 34.2	75 31.6	1855
*145	21		Drum's	Drane's	1855
*145		45	84 10.6	84 12.5	1855
*145		38	89 54.5	89 48.5	1855
*151	3		Fourchue	Fourchue Island	1855
*151	3			[In heading of column 7,] Geographical miles	1855
*151	3		oz	of z	1855
*153			[Large table, column 8, line 2,] 1.63	1.03	1855
*153				[Same table, column 1, second argument of moon's declination, zero ought to be lowered 1 line.]	1855
*158	26		colors	lines	1855
*159			[Table No. 1, under second maximum for Sandy Hook,] 1.00.	0.00	1855
*159			[Table No. 1, under 4th maximum for Cape Henry,] 4.42	3.42	1855
*159			[Table No. 1, under second maximum for final value,] 4.01	4.00	1855
*160	51		full line	shade	1855
*160	52		lines	shades	1855
*165		28		Wind light and variable	1855
*165		24		Moderate wind from S. W	1855
*165		3	×	+	1855

a*138.

ERRATA, 1854—Continued.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
*166	1		66	166	1855
*167		11	7° S. (7° W.)	7° (S. 7° W.)	1855
*168	7		par-tide	particle	1855
*172	3		depth	breadth	1855
*174		6	N. 35	N. 35 E	1855
*181	14			Transpose commas after "transits" so as to stand after "declinations."	1855
*182	6		[Column 4,] 22	27	1855
*182	6		[Column 9,] 16	13	1855
*182	6		[Column 10,] 18	13	1855
*183			[In heading of Table II,] Smithville, S. C	Smithville, N. C	1855
*185			[Upper table, last line, column 3,] 5.3	58	1855
*185			[Upper table, line 2 from the bottom, column 3,] 0.0	0.3	1855
*190	14		1854	1853	1855
*192	12		D	*L*	1855
*192	15		E	*D*	1855
*192		5	pressure	presence	1855
*194	27		cars	burs	1855
*198	32		investigated	invested	1855
*198	35		quoted	coated	1855
*204	12		[*Et passim*,] *gerne*	*genre*, (French)	1855
			[In index,] Lieut., &c	Capt. W. R. Palmer, U. S. A	1855

ERRATA, 1855.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
5	1		[Strike out] of		1855
6		20	259°	25°	1855
21	16		seventy	seventy-five	1855
41		18		With three buoys to mark its outline, this channel, &c	1855
138 to 140				Under heading, *Winyah Bay*, increase all longitudes by 3′ 56″.7. The correction does not affect azimuth or distances	1855
268	22		+	—	1855
268				At bottom insert "—" before numerator of fraction	1855
269			[In first and second equations,] K	*k*	1855
269	21			δx_m, the correction of the moon's co-ordinate in right ascension for the instant denoted by s	1855
269	23			δx_s, the correction of the star's co-ordinate in right ascension for the year 1840	1855
269		6	δp	δb	1855
270 to 272				The formulas of these pages are affected with errors, which will require that they be reprinted in the next report of the survey	1855
273				[Line 9 of table, (column y_s,)] 1861.69	1855
273				[Line 24 from bottom of table, (column β',)] 24° 9′ 22″.06.	1855
273				[Line 17 from bottom of table, (column x_s,)] 596.85	1855
273				[Line 19 from bottom of table, (column x_s,)] + 127.46	1855
273				[Line 3 from bottom of table, (column y_s,)] — 889.60	1855
275		21	was	were	1855
288				[Lines 21 and 22 of table,] Insert ζ and α at beginning; and [of last four lines,] ε, a, α and μ	1855
314		4		Insert ε_Y in middle of heading	1855
335				[Second table,] Insert *d* in heading of fifth column	1855
342			[Line 9 of Appendix No. 51,] has	had	1855
345		5	9*h*. 42*m*	7*h*. 49*m*	1855
349			[Table I, column 3, second line from bottom,] 12*h*. 12*m*	12*h*. 6*m*	1857
351				[Table II, last column,] Subtract 6*m*. from quantities in last column.	1857
351			[Table 3, column 4, line 4,] 10.0	11.0	1857
353				[Line 6,] Strike out line 6	1857

ERRATA, 1855—Continued.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
354	......	......	....	[Tables IV and V,] Subtract 6 *m.* from all the quantities in the columns headed from 0 to 7.	1857
354	......	10	13*h.* 3*m*	12*h.* 57*m*	1857
354	......	9	25*h.* 0*m*	24*h.* 54*m*	1857
354	......	9	1*h.* 0*m*	0*h.* 14*m*	1857
354	......	5	20*m*	14*m*	1857
354	......	4	24*h.* 21*m.* and 0.21	24*h.* 15*m.* and 0.15	1857
358	......	......	[Table X, line 7,] 1.1, 1.5, 0.6	1.9, 2.4, 1.7	1857
379	13	......	Jan José	San José	1857
379	18	......	that mountain	Mount Diablo	1857
380	9	......	suggests	suggest	1857
380	10	......	....	Insert a comma after "direction"	1857
387	17	......	practically	economically	1857
388	25	......	Sancelito	Saucelito	1857
392	24	......	of the boring shells	of boring shells	1857
392	26	......	granite	granitic	1857
394	......	21	anti-clinal	anticlinal	1857
394	......	2	were	was	1857
395	1	......	Quarternary	Quaternary	1857
395	12	......	primogenius	primigenius	1857
395	19	......	Exudes	exude	1857
395	......	......	[Foot-note,] practical	practicable	1857
396	16	......	former	older	1857

ERRATA, 1856.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
41	......	25	*eastern*	*western*	1856
59	......	8	6.8	6.1	1856
59	......	7	8.3	7.3	1856
65	......	4	five feet and seven-tenths	5.9	1856
65	......	3	seven	6.7	1856
130	......	......	[Table IX, 3d hour of col. 5, "from small low water to large high,"] 3.0.	3.3	1856
130	......	......	....	[IX, 6th hour of columns 1 to 7, "small ebb," &c.] 0.3, 0.5, 0.8, 1.2, 1.7, 2.4, 3.0.	1856
169	5	......	drawing B	drawing. B, &c.	1856
169	17	......	....	[After "silver frame,"] Insert "the pivot-holes being bushed with platinum."	1856
169	......	4	chronographic recording in Bond's Chronographic Register.	recording on a chronographic register regulated by Bond's spring-governor.	1856
170	5	......	B and B′	B′ and B″	1856
170	6	......	by intervening thin plates of ivory, (not represented in the figure.)	by an intervening plate of ivory	1856
170	7	......	B and B′	B′ and B″	1856
170	15	......	slips	drops	1856
170	19	......	[*Dele*] is of the same diameter as A′ and	....	1856
170	24	......	slips	drops	1856
170	25	......	B	B′	1856
170	......	21	....	[After "register,"] Insert "of which the regulator was".	1856
170	......	11	....	[After "pendulums,"] Insert "the device of Mr. Kerrison, of Philadelphia."	1856
264	......	21	....	within a century it has increased nearly a mile, and at about the rate of one-sixteenth of a mile on the average in the twelve years.	1856
325	18	......	investigation	investigator	1857
327	......	20	themics . . . . meteorology	thermics . . . . metrology	1857

ERRATA, 1857.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
1	1	......	OFFICE	STATION	1857
111	15	......	1889	18 sq. m	1858
144	26	......	1855	1850	1857
182	......	......	["Key West—over Northwest Channel Bar;" "Low water of spring-tides,"] 17.7.	11.7.	1857
183	......	......	["Santa Cruz Harbor—anchorage," in fifth column of figures,] 26.6.	25.7	1857
183	......	......	["San Francisco Harbor—on the bar," in sixth column of figures,] 36.4.	37.4	1857
183	......	......	["At best wharves," sixth column,] 23.4	24.4	1857
190	26	......	covered	curved	1857
226	19, 29	......	Lynn	Lyme	1858
272	37	......	40° 56′ 06″.88	40° 56′ 06″.38	1858
272	......	8	40° 51′ 09″.44	40° 51′ 07″.44	1858

ERRATA, 1858.

Page.	Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
114	......	19	inspector	engineer	1859
114	......	16	in the harbor	outside of the harbor	1859
122	......	......	[After "tidal observations," *dele*] "with the self-registering tide-gauge."		1859
193	10	......	a	a_1	1858
193	......	10	a	a_1	1858
235	13	......	[*Dele*] $\frac{3000}{3487}$		1858
359	20	......	10″.3	20″.4	1858
359	21	......	29″.0	28″.8	1858
381	......	13	45′.3	45″.3	1858
429	3	......	123° 14	123° 14′	1858
442	9	......	25″.6	25″.8	1858

ERRATA, 1859.

Page.	Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
36	1	......		Insert "δ" before "Ursæ minoris"	1859
73	......	11	western	eastern	1860
98	7	......	frustrum	frustum	1860
98	......	1	reading	value	1860
145	......	15	Thunderbolt	Humboldt	1860
238	......	......	Thunderbolt	Humboldt	1860
279	16	......	40° 50′	4° 50′	1860
280	10	......	for	from	1860
293	18	......	1840	in 1840	1860
317	19	......	frustrums	frustums	1860
336	......	......	[Co-ordinates of curvatures; latitude 9°, column 4, longitude 2°,] 400.	600	a1866
359	......	......	[In title,] Sketch No. 40	Sketch No. 39	1860

a Page 141.

ERRATA, 1860.

Page.	Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
19	23	......	Lieut.	Commander	1860
54	1	......	inside the shore	inside shore	1860
161	......	12	having	leaving	1860
239	......	10	23 S	28 S	1860
275	4	......	25.18	23.22	1860
275	5	......	24.36	23.87	1860
275	7	......	0.86	0.37	1860
275	8	......	.253	.240	1860
275	9	......	18s.76	17s.52	1860
275	10	......	20	21	1860
275	14	......	18.76	17.52	1860

ERRATA, 1860—Continued.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
275	15	......	29.30	28.06	1860
275	18	......	30.7	31.6	1860
275	21	......	31.8	30.6	1860
275	22	......	29.3	28.1	1860
275	23	......	29.33	29.09	1860
275	24	......	28.72	28.95	1860

ERRATA, 1861.

Page.	Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
232	......	15	41°	43°	1862

ERRATA, 1862.

Page.	Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
12	......	5	1861–'62	1860–'61, and is much diminished from those of 1861–'62.	1862
178	13	......	Sketch No. 50	Sketch No. 48	1862
182	......	10	Sketch No. 50	Sketch No. 48	1862
233	3	......	[To expression for "$12b_2$,"]	Add "$+ S_3 - S_9 + S_{15} - S_{21}$"	1866
254	......	6	9. 5	0.5	1862
272	......	13	Sergus	Sergas	1862
272	......	17	of Sergus	"Las Sergas." The full title of the book is "Las Sergas del Mey Esforzado Cabalero Esplandian hijo del Excelente re Amadis de Gaula."	1862
275	7	......	pages	pages 45–49	1862
285	7	......	page	page 15	1862
286	......	16	side	N. W. side	1862
288	......	12	12″.9	11″.6	1862
290	9	......	10.″2	09″.8	1862
292	......	17	bend	trend	1862
296	12	......	58″.1	51″.8	1862
297	5	......	17″	11″	1862
299	6	......	55	5.5	1862
299	21	......	of Point	off Point	1862
299	......	8	undergo is	undergoes	1862
301	......	11	10″.0	03″.7	1862
302	23	......	56″.9	50″.5	1862
303	8	......	37″.4	31″.0	1862
303	......	2	southward	southward of Point Lobos	1862
303	......	1	Point Lobos	it	1862
304	12	......	intimated	ascertained	1862
307	18	......	straight	strait	1862
316	......	15	moon	noon	1862
323	14	......	$12,000,0000	$12,000,000	1862
325	8	......	are found	is found	1862
327	7	......	37 59 39.4	37° 59′ 39″.4	1862
327	......	2	levated	elevated	1862
328	......	21	31.6″, 54.9″	31″.6, 54″.9	1862
328	......	11	islet	islets	1862
329	4	......	4¼	3½	1862
329	19	......	four	three	1862
355	......	8	127° 58′	123° 58′	1862
359	12	......	after	before	1862
360	10	......	311–315	44–48	1862
364	21	......		Between 21 and 22 insert ("Supplement,") '62, p. iv, v."	1862

ERRATA, 1862—Continued.

Page.	Line from— Top.	Bottom.	Misprinted.	Corrected.	Where corrected.
364	29	......	bank	shoal	1862
364	......	9	bank	shoal	1862
365	6	......	is	are	1862
365	11	......	bank	shoal	1862
367	18	......	Columbia	Columbia's	1862
370	......	22		Add: "from the south bar"	1862
371	12	......	which	it	1862
376	14	......	377	110	1862
376	......	18	is	are	1862
379	......	4		[In the blank,] Insert "110"	1862
383	......	4	ow . . findl	low . . find	1862
387	2	......	refitted their ships here	were refitted here	1862
387	30	......	and ——	136-148	1862
389	......	4	for good with holding	with good holding	1862
392	3	......	northwest	northeast	1862
396	......	17	[Strike out] first		1862
399	16	......		[In blank space,] Insert "distant"	1862
402	......	8	Cordowa	Cordova	1862
404	......	18	sweeps	sweep	1862
408	24	......	the shore	the eastern shore	1862

ERRATA, 1863.

None.

ERRATA, 1864.

143	......	2	40″.009	41″.009	1866

ERRATA, 1865.

198	......	......	[In triangle 20, distance opposite Humpback,] 22161.352	26161,352	1866

ERRATA, 1866.

VII	......	15	104	140	1871

ERRATA, 1867.

289	......	22	Eschotty	Escholtz Bay	1871

ERRATA, 1868.

None.

ERRATA, 1869.

165	15	......	waved	was notched	1871
165	15	......	and very	and steadily melted away very	1871
176	......	9	1*h*. 44*m*. 06.3*s*	1*h*. 41*m*. 06.3*s*	1871

ERRATA, 1870.

Page.	Line from— Top.	Line from— Bottom.	Misprinted.	Corrected.	Where corrected.
203	......	......	Ξ should be subscript in all the formulas instead of on the line.	......	1870
207	......	......	At the end of first paragraph, strike out the last sentence.	......	1870
207	......	12	*induced*	*used*	1870

LIST OF SKETCHES.

PROGRESS-SKETCHES.

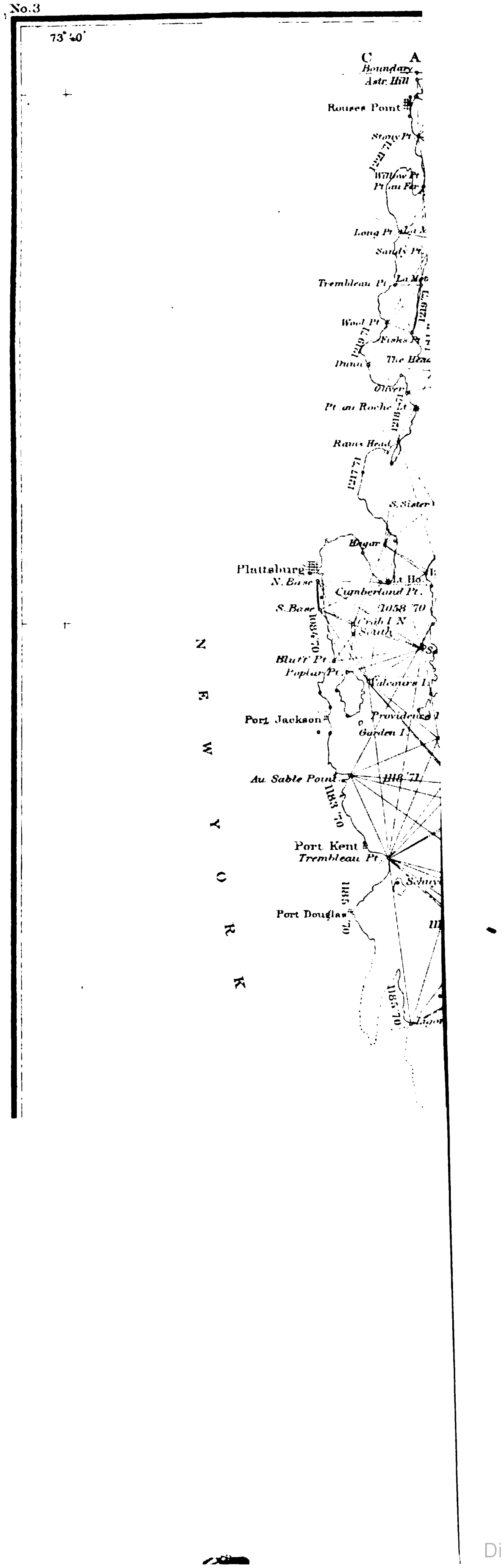
GENERAL COAST-CHARTS.

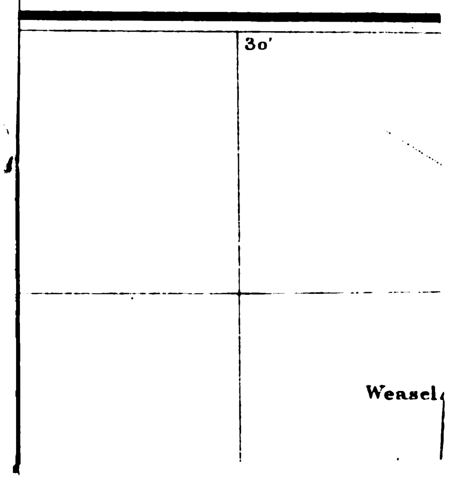
COAST-CHARTS.

RIVER AND HARBOR CHARTS.

ILLUSTRATIONS.

No. 3

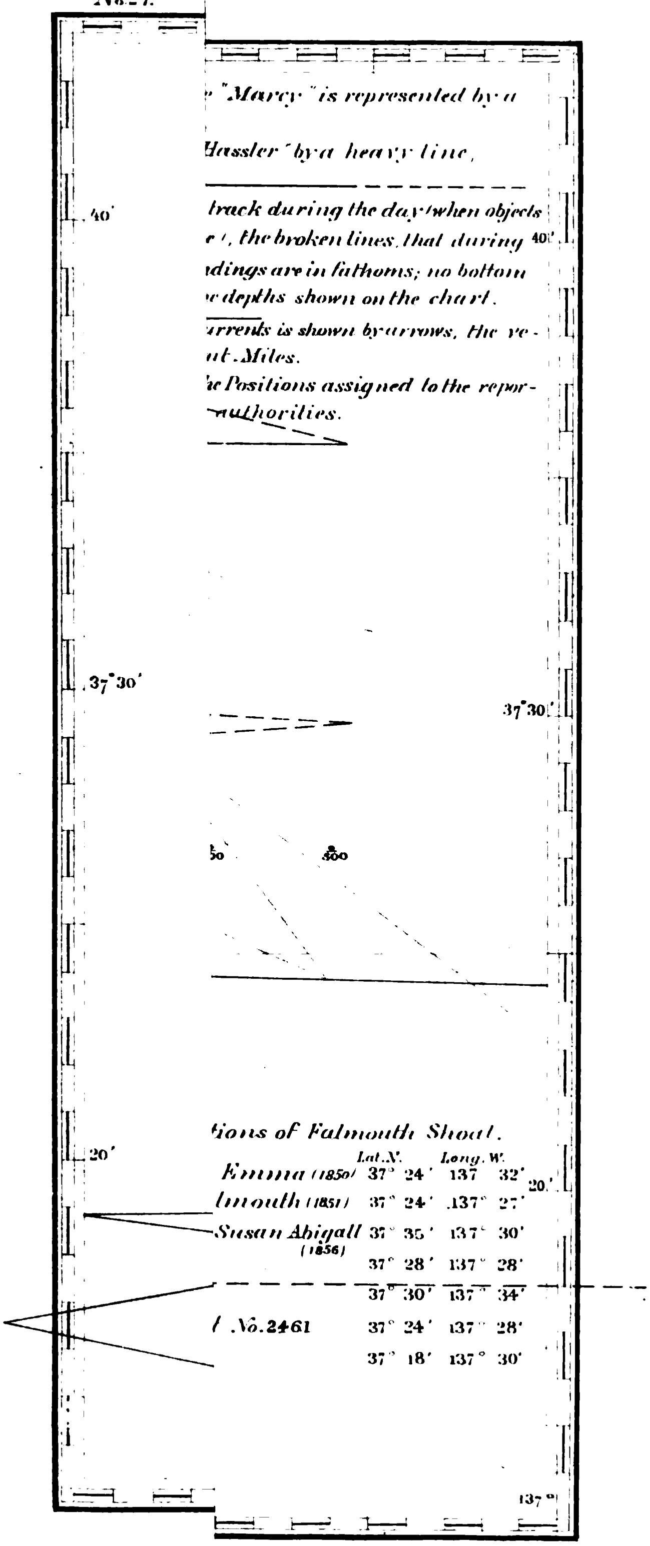

73° 40'
C A
Boundary
Astr. Hill
Rouses Point
Stony Pt.
Willow Pt.
Pt. au Fer
Long Pt.
Sandy Pt.
Trembleau Pt.
Wool Pt.
Fisks Pt.
Dunn's
Oliver
Pt. au Roche Lt.
Rams Head
S. Sister
Bagar
Plattsburg
N. Base
Cumberland Pt.
S. Base
1058 '70
Crab I. N.
South
Bluff Pt.
Poplar Pt.
Valcours I.
Port Jackson
Providence I.
Garden I.
Au Sable Point
1118 '71
1183 '70
Port Kent
Trembleau Pt.
Port Douglas
1185 '70
N
E
W
Y
O
R
K


30'
Weasel


76° 20'
Bay

20

No. 27.



"Marcy" is represented by a
Hassler" by a heavy line,
track during the day (when objects
, the broken lines, that during
dings are in fathoms; no bottom
depths shown on the chart.
rrents is shown by arrows, the re-
ut. Miles.
e Positions assigned to the repor-
authorities.
40'
37°30'
20'
137°
ions of Falmouth Shoal.
Lat. N.
Long. W.
Emma (1850) 37° 24' 137 32'
lmouth (1851) 37° 24' 137° 27'
Susan Abigall (1856) 37° 35' 137° 30'
37° 28' 137° 28'
37° 30' 137° 34'
No. 2461 37° 24' 137° 28'
37° 18' 137° 30'

S OF

e slanting Capital
to 8 of height.

HESAPEAKE B.

TAGORDA BAY.

Height of Letters in Decimillimetres

s.

40 (a)

. Class.

30

20 (b)

15

10

6

st. Class.

30

Ledges, 1st. Class.

25

edges, 2nd. Class.

20

edges, 3rd. Class.

15

e BLOCK LETTERS

10

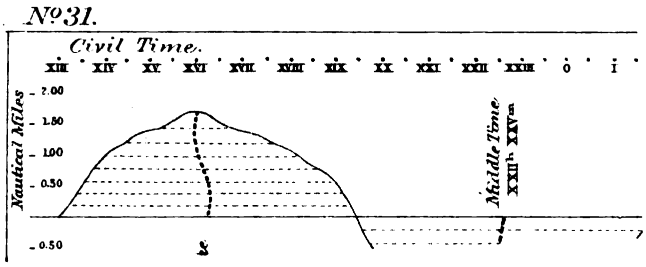
10

8

IONS.

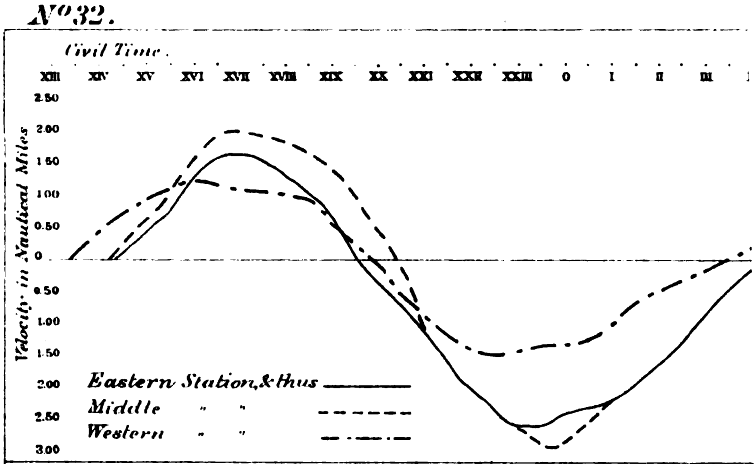
s.

s not in full capitals.
ing the word.
metres, but always

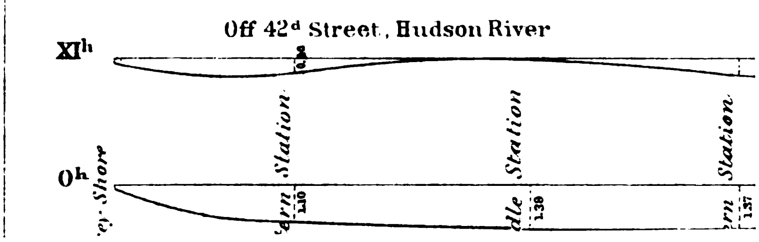


Nº 31.
Civil Time.
XIII XIV XV XVI XVII XVIII XIX XX XXI XXII XXIII 0 I
Nautical Miles
2.00
1.50
1.00
0.50
0.50
Middle Time
XXIIh XXVm

Nº 32.

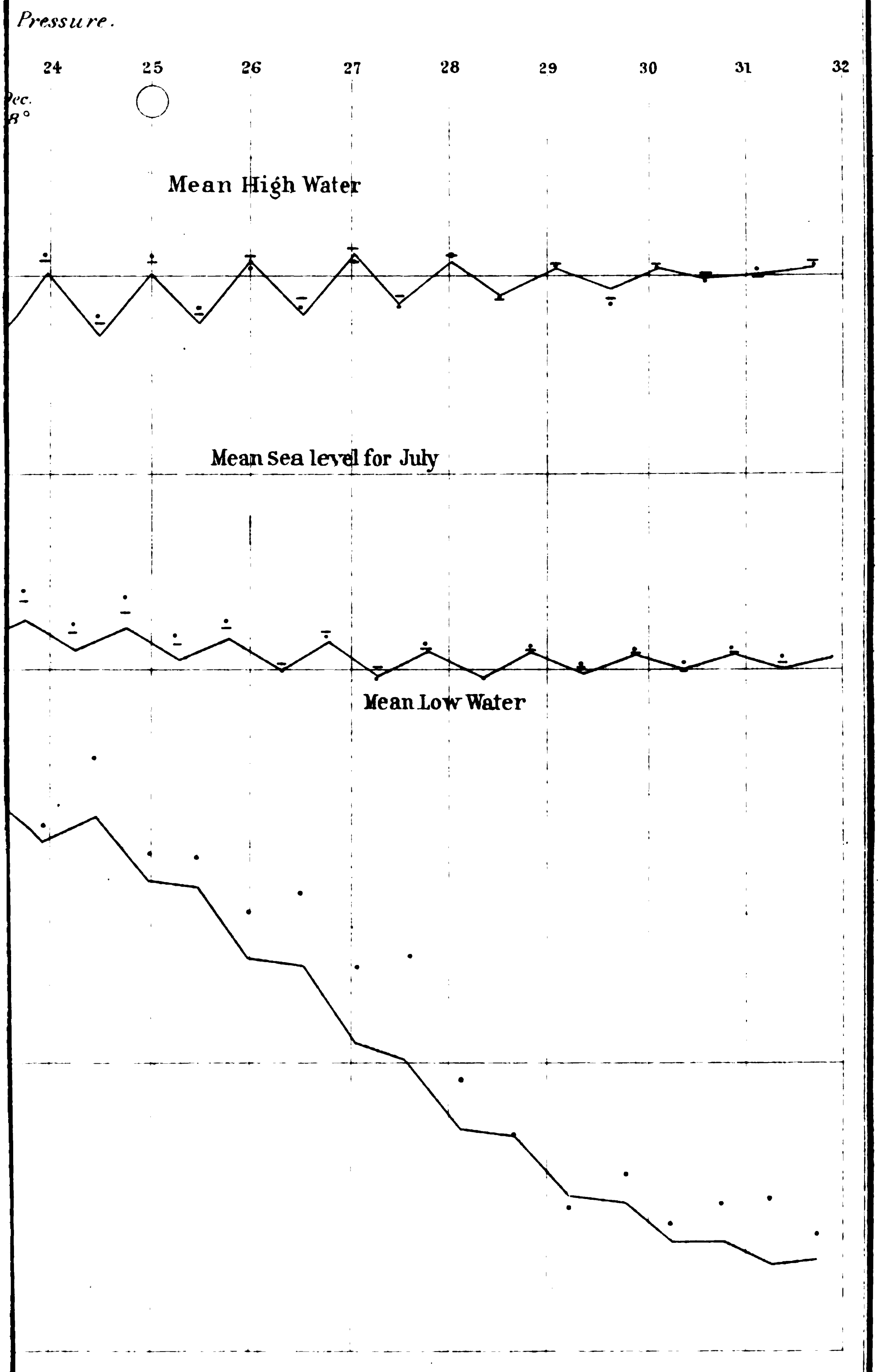


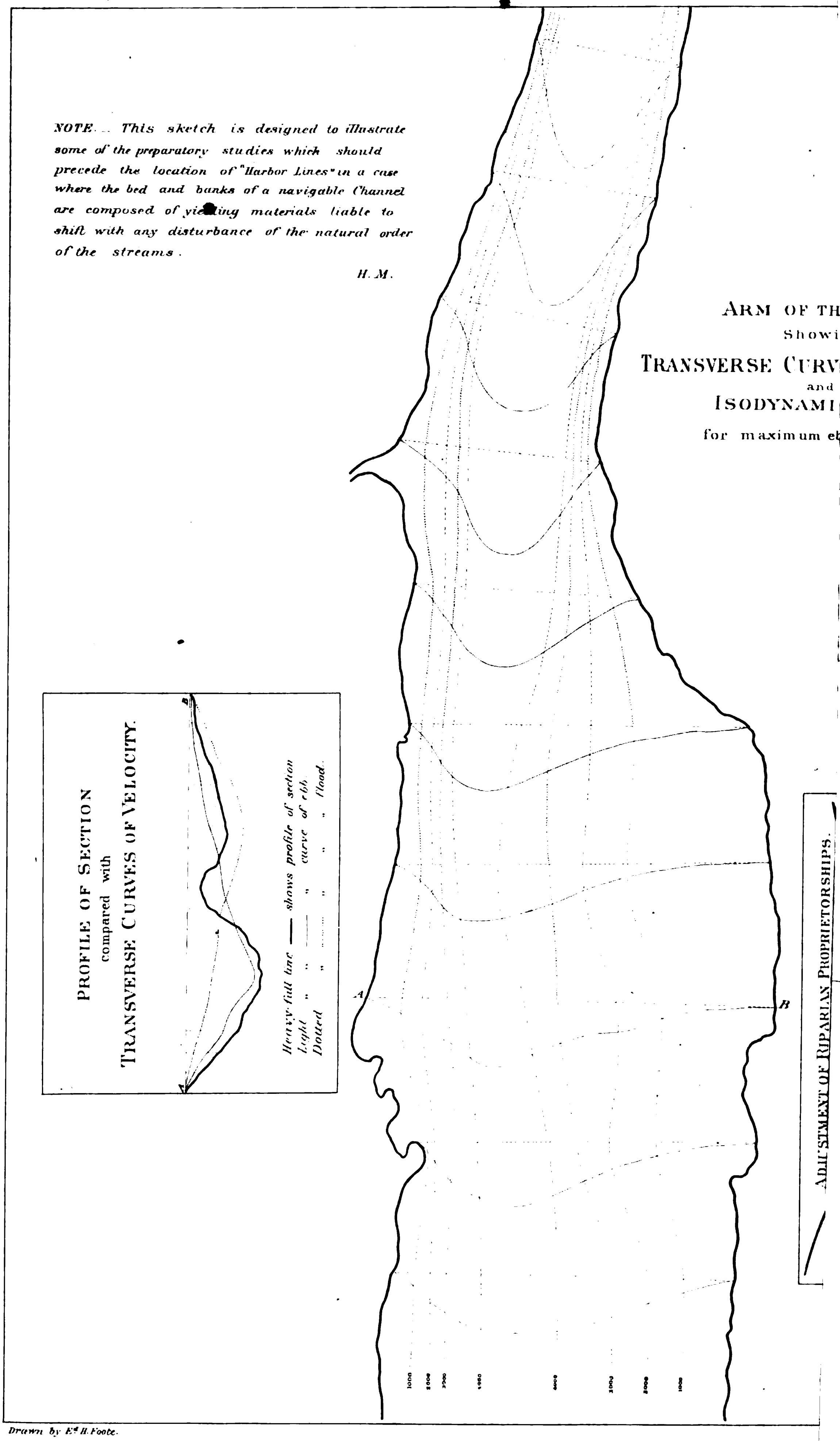
TRANSVER
IN THE




41°

changes of Atmospheric Pressure.





Drawn by Eᵈ H. Foote.